
CANDU-9 COMPACT SIMULATOR

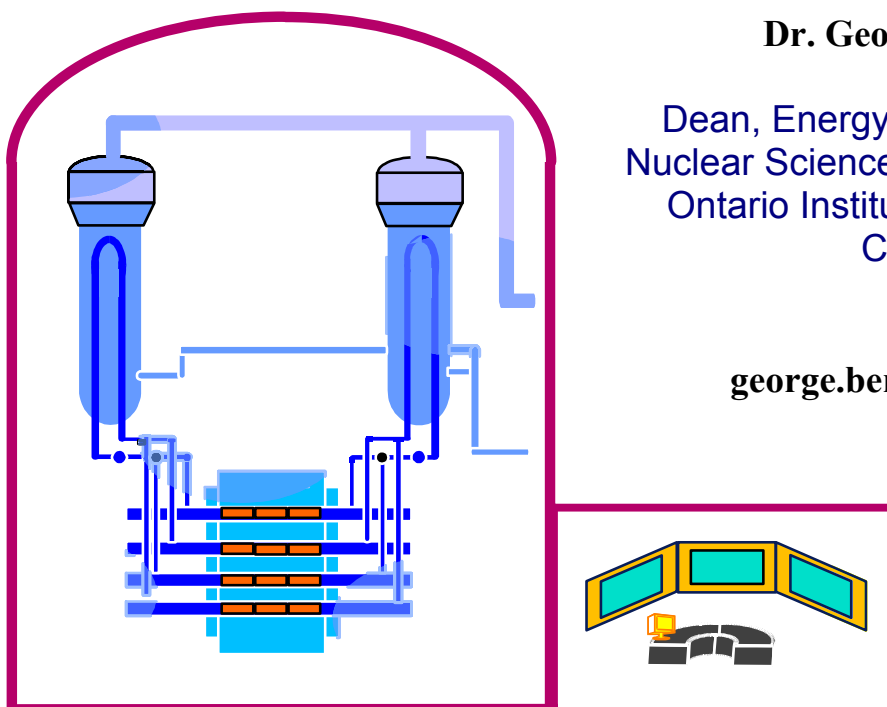
USER MANUAL

Lecture Notes
prepared by:

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1. INTRODUCTION

The CANDU-9 Compact Simulator was originally developed to assist Atomic Energy of Canada Limited (AECL) in the design of the plant display system. The specification for the Simulator required that the software be capable of execution on a Personal Computer (Pentium 100 or equivalent), to operate essentially in real time, and to have a dynamic response with sufficient fidelity to provide realistic signals to the plant display system. The Simulator also had to have a user-machine interface that mimicked the actual control panel instrumentation, including the plant display system, to a degree that permitted the development and operation of the simulator in a stand-alone mode, i.e. in the absence of the plant display system equipment. These features also made the Simulator suitable as an educational and training tool.

The minimum hardware configuration for the Simulator consists of an IBM compatible Personal Computer, 16 Mbytes RAM with 256 external Cache, at least 0.5 Mbytes enhanced IDE hard drive, 2 Mbytes VRAM, hi-resolution video card (capable of 1024x768), 15 inch or larger high resolution SVGA colour monitor, keyboard and mouse. The operating system is Windows for Workgroups 3.11 or Windows 95.

The requirement of having a single PC to execute the models and display the main plant parameters in real time on a high resolution monitor implied that the models had to be as simple as possible, while having realistic dynamic response. The emphasis in developing the simulation models was on giving the desired level of realism to the user. That meant being able to display those plant parameters which are most critical to operating the unit, including the ones that characterize the main process, control and protective systems. The current configuration of the Simulator is able to respond to the operating conditions normally encountered in power plant operations, as well as to many malfunctions conditions, as summarized in Table 1.

The simulation uses an on object oriented approach: basic models for each type of device and process to be represented are developed in FORTRAN. These basic models are a combination of first order differential equations, logical and algebraic relations. The appropriate parameters and input-output relationships are assigned to each model as demanded by a particular system application.

The interaction between the user and the Simulator is via a combination of monitor displays, mouse and keyboard. Parameter monitoring and operator controls implemented via the plant display system at the generating station are represented in a virtually identical manner on the Simulator. Control panel instruments and control devices, such as push-buttons and hand-switches, are shown as stylized pictures, and are operated via special pop-up menus and dialog boxes in response to user inputs.

This Operating Manual assumes that the user is familiar with the main characteristics of thermal nuclear power plants, as well as understanding the unique features of the CANadian Deuterium Uranium(CANDU) reactors.

Table 1: Summary of Simulator Features.

SYSTEM	SIMULATION SCOPE	DISPLAY PAGES	OPERATOR CONTROLS	MALFUNCTIONS
REACTOR	- neutron flux levels over a range of 0.001 to 110% full power, 6 delayed neutron groups - decay heat (3 groups) - all reactivity control devices - xenon and boron poison - reactor regulating system - reactor shutdown system	- reactivity control devices - shutdown rods - reactor regulating system	- reactor power and rate of change (input to control computer) - manual control of reactivity devices - reactor trip - reactor setback - reactor stepback	- reactor setback and stepback fail - one bank of control rods drop into the reactor
HEAT TRANSPORT	- two phase main circuit loop with four pumps, four steam generators, four equivalent reactor coolant channels - pressure and inventory control (pressurizer, degasser condenser, feed & bleed control, pressure relief) - operating range is zero power hot to full power	- main circuit - pressure control - pressurizer control - feed and bleed control - inventory control - degasser condenser control	- circulating pumps - pressurizing pumps - pressurizer pressure - pressurizer level - degas cond. pressure - degas cond. level - feed & bleed bias - isolation valves for: pressurizer, degasser cond., feed and bleed	- main circuit relief valve fails open - pressurizer relief valve fails open - pressurizer isolation valve fails closed - feed valve fails open - bleed valve fails open - reactor header break
STEAM & FEEDWATER	- boiler dynamics, including shrink and swell effects - steam supply to turbine and reheater - turbine by-pass to condenser - steam relief to atmosphere - extraction steam to feed heating - steam generator pressure control - steam generator level control - boiler feed system	- steam generator feed pumps - steam generator level control - steam generator level trends - steam generator pressure control - extraction steam	- level controller mode: computer or manual - manual level control gain & reset time - level control valve selection - level control isolation valve opening - extraction steam valves - feed pump operation	- all level control isolation valves fail closed - one level control valve fails open - one level control valve fails closed - all feed pumps trip - all safety valves open - steam header break - flow transmitter fails
TURBINE-GENERATOR	- very simple turbine model - mechanical power and generator output are proportional to steam flow - speeder gear and governor valve allow synchronized and non-synchronized operation	turbine-generator	- turbine trip - turbine run-back - turbine run-up and synchronization - atmospheric and condenser steam discharge valves	- turbine spurious trip - turbine spurious run-back
OVERALL UNIT	- fully dynamic interaction between all simulated systems - unit power regulator - unit annunciation - computer control of all major system functions	- overall unit - unit power regulator		

1.1 SIMULATOR STARTUP

- select program 'CANDU-9' for execution
- click anywhere on 'CANDU-9 Compact Simulator' screen
- click 'OK' to 'Load Full Power IC?'
- the Simulator will display the 'Plant Overview' screen with all parameters initialized to 100% Full Power
- at the bottom right hand corner click on 'Run' to start the simulator

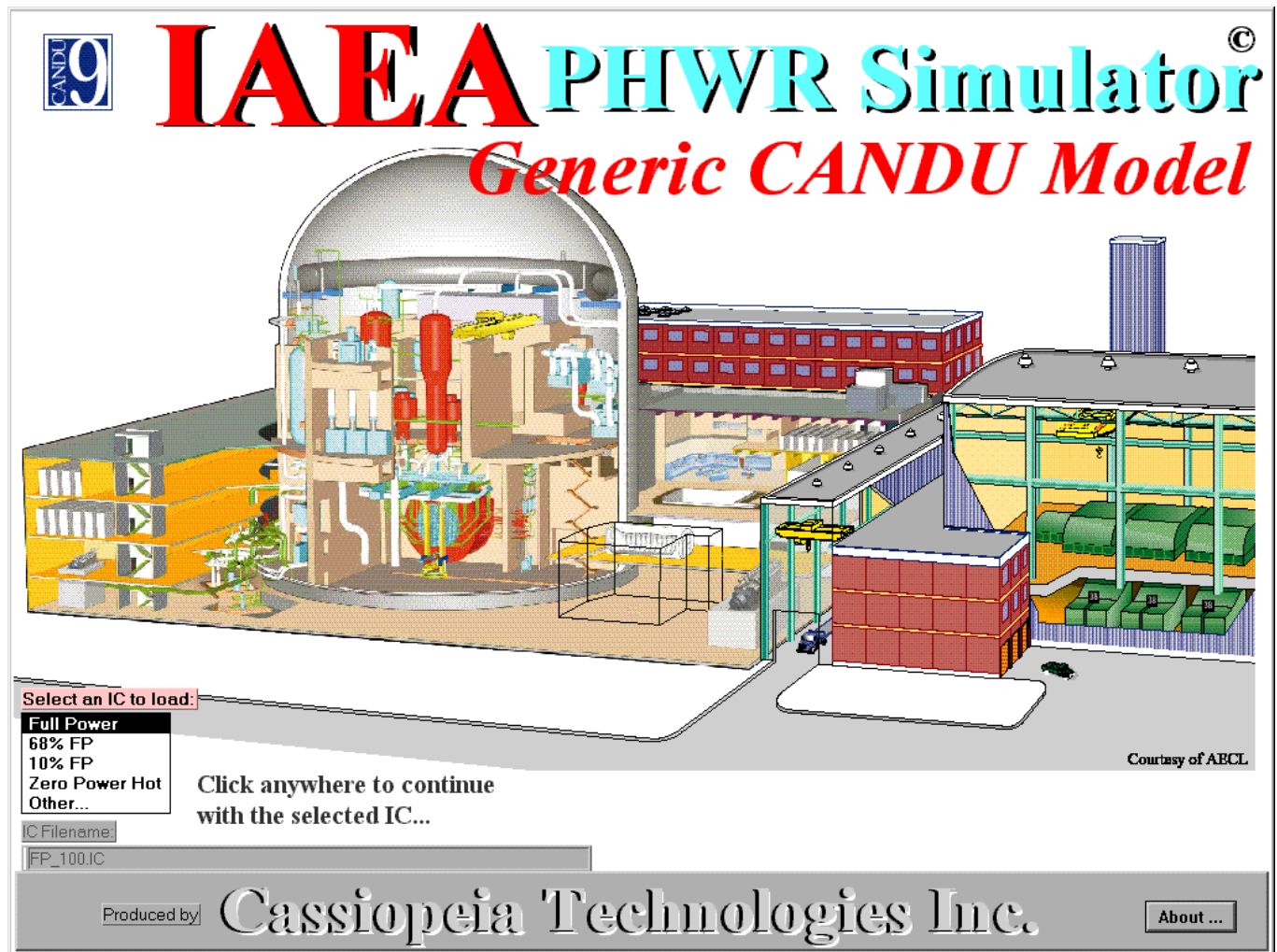
1.2 SIMULATOR INITIALIZATION

If at any time you need to return the Simulator to one of the stored Initialization Points, do the following:

- 'Freeze' the Simulator
- click on 'IC'
- click on 'Load IC'
- click on 'FP_100.IC' for 100% full power initial state
- click 'OK' to 'Load C:\AECL_P2\FP_100.IC'
- click 'YES'
- click 'Return'
- Start the Simulator operating by selecting 'Run'.

1.3 LIST OF CANDU 9 COMPACT SIMULATOR DISPLAY SCREENS

1. Plant Overview
2. Shutdown Rods
3. Reactivity Control
4. PHT Main Circuit
5. PHT Feed & Bleed
6. PHT Inventory Control
7. PHT Pressure Control
8. Bleed Condenser Control
9. Steam Generator Feed Pumps
10. Steam Generator Level Control Steam
11. Generator Level Trends
12. Steam Generator Level Manual Ctrl
13. Extraction Steam
14. Turbine Generator
15. RRS / DPR
16. UPR



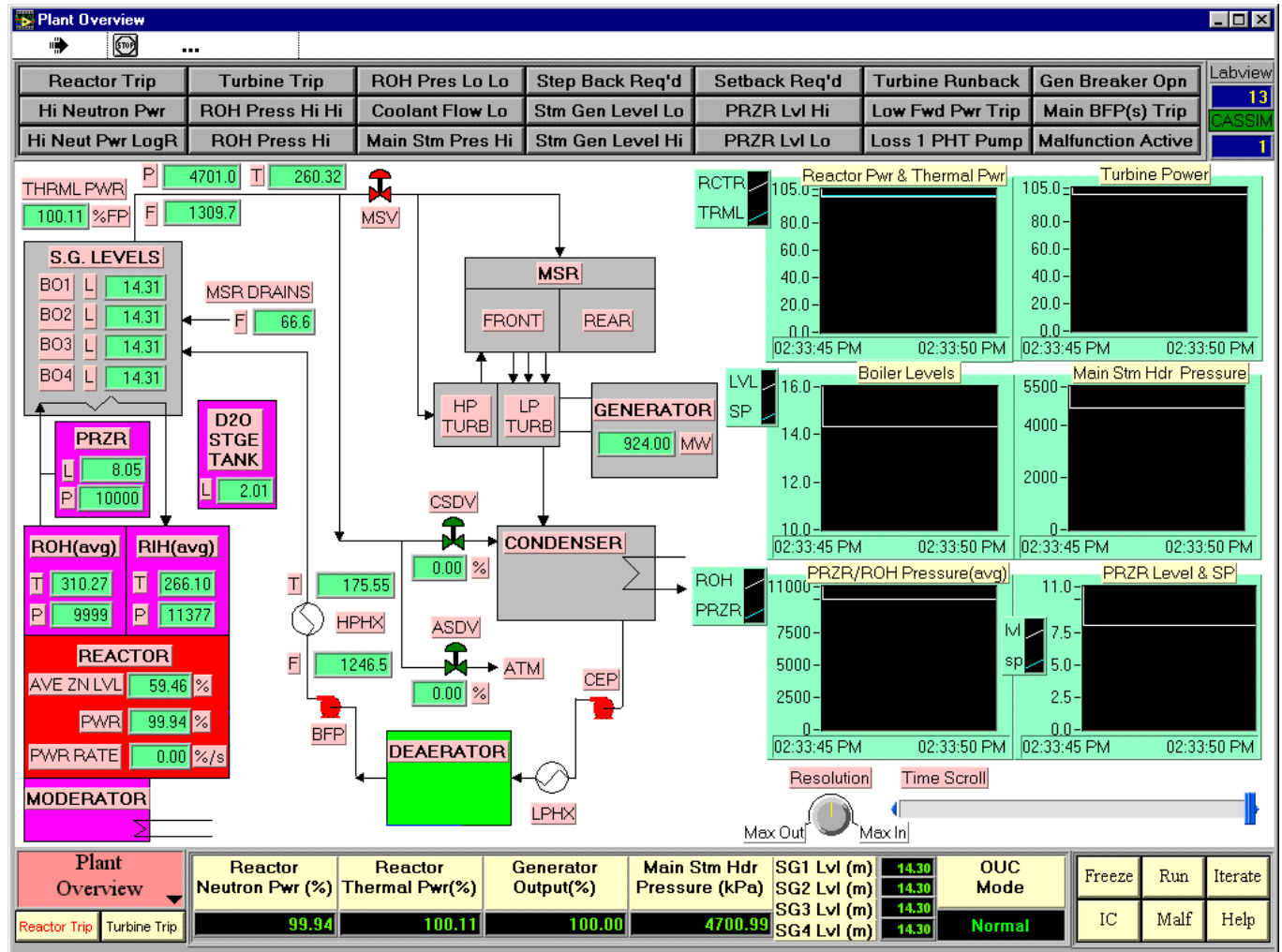
1.4 COMPACT SIMULATOR DISPLAY COMMON FEATURES

The CANDU 9 Compact Simulator is made up of 16 interactive display screens or pages. All of these screens have the same information at the top and bottom of the displays, as follows:

- top of the screen contains 21 plant alarms and annunciations; these indicate important status changes in plant parameters that require operator actions; each of these alarms will be discussed as part of the system that is generating it and/or is involved in the corrective action;
- top right hand corner shows the simulator status:
 - ⇒ the window under 'Labview' (this is the proprietary software that generates the screen displays) has a counter that is incrementing when Labview is running; if Labview is frozen (i.e. the displays cannot be changed) the counter will not be incrementing;
 - ⇒ the window displaying 'CASSIM' (this is the proprietary software that computes the simulation responses) will be green and the counter under it will not be incrementing when the simulator is frozen (i.e. the model programs are not executing), and will turn red and the counter will increment when the simulator is running;
- to stop (freeze) Labview click once on the 'STOP' sign at the top left hand corner; to restart 'Labview' click on the ⇒ symbol at the top left hand corner;
- to start the simulation click on 'Run' at the bottom right hand corner; to 'Stop' the simulation click on 'Freeze' at the bottom right hand corner;
- the bottom of the screen shows the values of the following major plant parameters:
 - ⇒ Reactor Neutron Power (%)
 - ⇒ Reactor Thermal Power (%)
 - ⇒ Generator Output (%)
 - ⇒ Main Steam Header Pressure (kPa)
 - ⇒ Steam Generator Level (m)
 - ⇒ OUC Mode ('Normal' or 'Alternate')
- the bottom left hand corner allows the initiation of two major plant events:
 - ⇒ 'Reactor Trip'
 - ⇒ 'Turbine Trip'

these correspond to hardwired push buttons in the actual control room;

- the box above the Trip buttons shows the display currently selected (i.e. 'Plant Overview'); by clicking and holding on the arrow in this box the titles of the other displays will be shown, and a new one can be selected by highlighting it;
- the remaining buttons in the bottom right hand corner allow control of the simulation one iteration at a time ('Iterate'); the selection of initialization points ('IC'); insertion of malfunctions ('Malf'); and calling up the 'Help' screen.

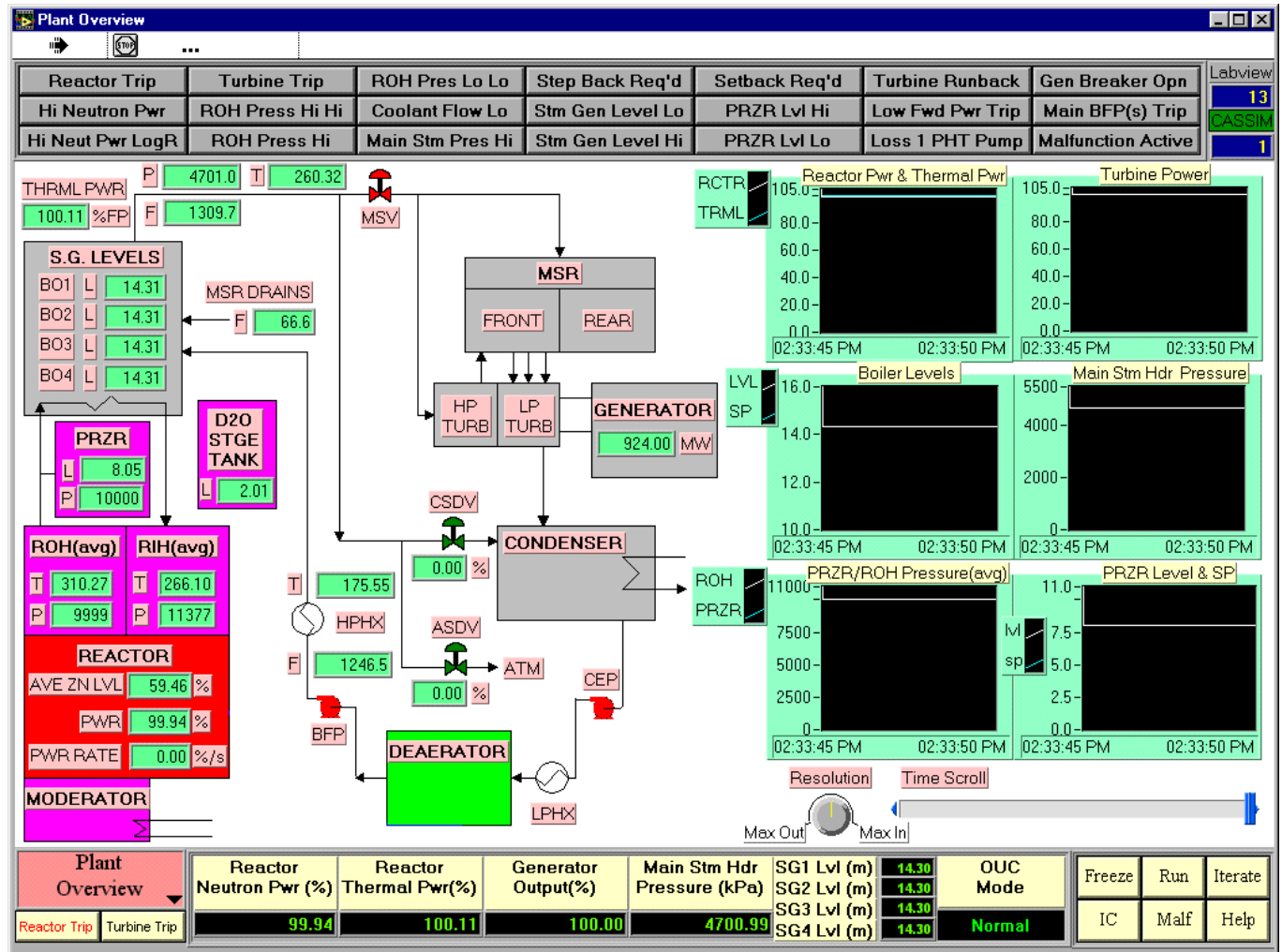


2. SIMULATOR DISPLAY PAGES

2.1 PLANT OVERVIEW PAGE

Shows a 'line diagram' of the main plant systems and parameters. No inputs are associated with this display. The systems and parameters displayed are as follows (starting at the bottom left hand corner):

- MODERATOR system is not simulated
- REACTOR is a point kinetic model with six groups of delayed neutrons, the decay heat model uses a three group approximation; reactivity calculations include reactivity control and safety devices, Xenon, voiding in channels and power level changes. The parameters displayed are:
 - ⇒ Average Zone Level (% full)
 - ⇒ Neutron Power (% full power)
 - ⇒ Neutron Power Rate (%/ second)
- Heat Transport main loop, pressure and inventory control systems are shown as a single loop on the Plant Overview display, additional details will be shown on subsequent displays. The parameters displayed are:
 - ⇒ Reactor Outlet Header (ROH) and Reactor Inlet Header (RIH) average Temperature (°C) and Pressure (kPa)
 - ⇒ Pressurizer Level (m) and Pressure (kPa); D₂O Storage Tank level (m)
- The four Steam Generators are individually modeled, but only the level measurements are shown separately, for the flows, pressures and temperatures average values are shown. The parameters displayed are:
 - ⇒ Boiler 1, 2, 3, 4 Level (m)
 - ⇒ Steam Flow (kg/sec)
 - ⇒ Steam Pressure (kPa)
 - ⇒ Steam Temperature (°C)
 - ⇒ Moisture Separator and Reheater (MSR) Drains Flow (kg/sec)
 - ⇒ Status of control valves is indicated by their colour: green is closed, red is open; the following valves are shown for the Steam System:
 - Main Steam Stop Valves (MSV) status only
 - Condenser Steam Discharge Valves (CSDV) status and % open
 - Atmospheric Steam Discharge Valves (ASDV) status and % open
- Generator output (MW) is calculated from the steam flow to the turbine
- Condenser and Condensate Extraction Pump (CEP) are not simulated
- Simulation of the feedwater system is very much simplified; the parameters displayed on the Plant Overview screen are:
 - ⇒ Total Feedwater flow to the steam generators (kg/sec)
 - ⇒ Average Feedwater temperature after High Pressure Heater (HPHX)
 - ⇒ Status of Boiler Feed Pumps (BFP) is indicated as red if any pumps are 'ON' or green if all the pumps are 'OFF'



Six trend displays show the following parameters:

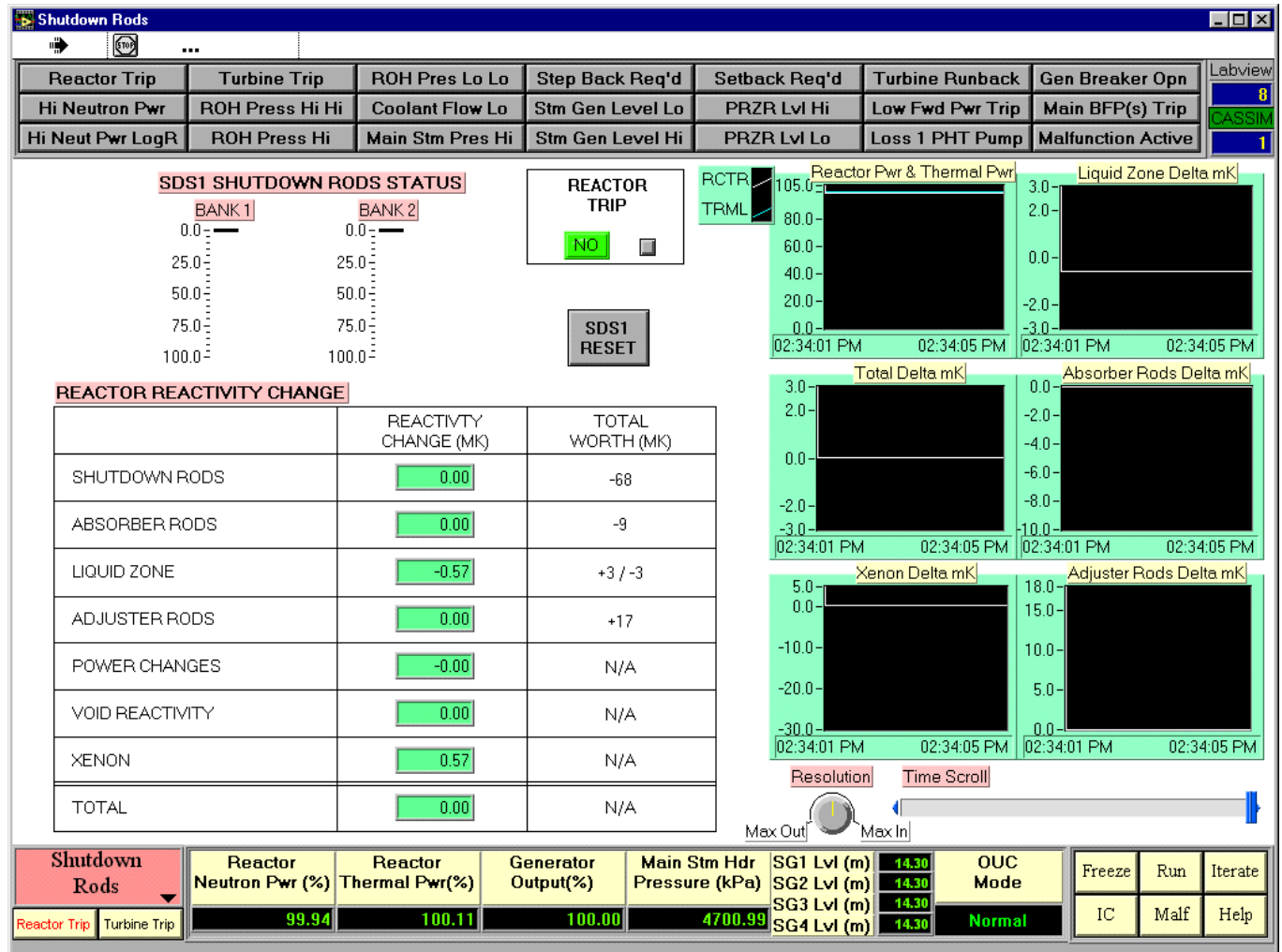
- Reactor Neutron Power and Reactor Thermal Power (0-100%)
- Turbine Power (0-100%)
- Boiler Levels - actual and setpoint (m)
- Main Steam Header Pressure (kPa)
- Pressurizer and Reactor Outlet Header (average) Pressure (kPa)
- Pressurizer Level - actual and setpoint (m)

Note that while the simulator is in the 'Run' mode, all parameters are being continually computed and all the displays are available for viewing and inputting changes.

2.2 SHUTDOWN RODS PAGE

The screen shows the status of SDS#1, as well as the reactivity contributions of each device and physical phenomenon that is relevant to reactor operations.

- The positions of each of the two SDS1 SHUTDOWN ROD banks are shown relative to their normal (fully withdrawn) position.
- REACTOR TRIP status is shown as NO (green) or YES (yellow), the trip can be reset here (as well as on the RRS / DPR page); note that SDS1 RESET must also be activated before RRS will begin withdrawing the Shutdown Rods.
- The REACTIVITY CHANGE of each device and parameter from the initial 100% full power steady state is shown, as well as the range of its potential value.
 - ⇒ Note that reactivity is a computed not a measured parameter, it can be displayed on a simulator but is not directly available at an actual plant.
 - ⇒ Note also that when the reactor is critical the Total reactivity must be zero.



2.3 REACTIVITY CONTROL PAGE

This screen shows the Limit Control Diagram, and the status of the three reactivity control devices that are under the control of RRS.

- The Limit Control Diagram displays the Operating Point in terms of Power Error and Average Liquid Zone level.

POWER ERROR = ACTUAL POWER - DEMANDED POWER

- ⇒ If power error is negative, more (positive) reactivity is needed, hence liquid zone level will decrease and if this is insufficient, absorber rods and adjuster rods will be withdrawn from the reactor.
- ⇒ If power error is positive, negative reactivity is needed, hence liquid zone level will increase and if this is insufficient, absorber rods and adjuster rods will be driven into the reactor.
- ⇒ The Power Error computation includes the difference between the magnitudes and rates of change of the actual and demande powers, each multiplied by a controller constant. The above simple fomula is written only as a quick reminder of the meaning of the power error term.
- The ABSORBERS are moved in two banks, and are normally outside the core. They are moved by RRS if AUTO is selected, or can be moved manually if their control is placed into the MANUAL mode. Note that reactor power should not exceed 80%FP if either of the Control Absorbers is not fully out of the core.
- The ADJUSTERS are moved in eight banks, and are normally fully inserted into the core. They are moved by RRS if AUTO is selected, or manually if they are placed in MANUAL mode. Note that maximum reactor power should be reduced by 5%FP for each Adjuster Rod bank that is not in the fully inserted position.
- The liquid zone system is simlified on this model of the Simulator, and includes only one zone that represents all of the 14 liquid zones. The average zone level, water outflow and inflow rates are displayed. When the inlet valve is in the AUTO position, it is under the control of RRS. By selecting manual control, the openingof the inlet vae and hence the zone level can be manually controlled.
- The speed of the Absorbers and Adjusters is displayed but cannot be controlled from this page.

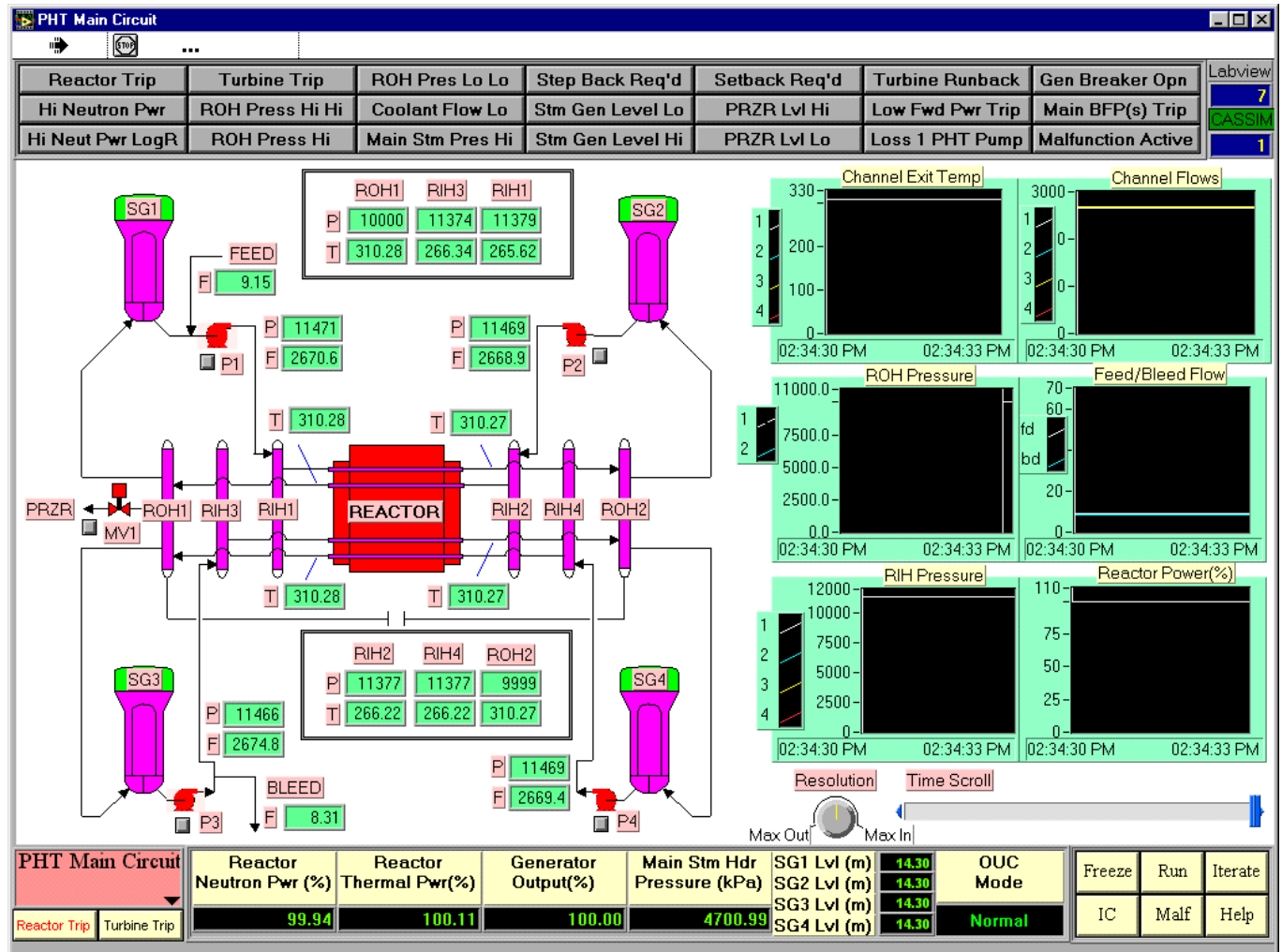
2.4 PHT MAIN CIRCUIT

This screen shows a simplified layout of the main heat transport system: the 480 coolant channels are represented by only four channels, two per loop showing the opposite directions of flow in the figure of eight configuration of each loop.

Starting from fuel channel number 1 at the reactor and following the direction of coolant flow, the system components and parameters shown are:

- average channel exit temperature (°C)
- ROH2 (note that ROH2 pressure and temperature are shown in the box below the reactor)
- SG2
- P2 (selection allows 'START', 'STOP' and 'RESET' operations)
- Pressure (kPa) and temperature (°C) at the outlet of P2
- RIH2 (note that RIH2 pressure and temperature are shown in the box below the reactor)
- fuel channel number 2
- average channel exit temperature (°C)
- ROH1 (note that ROH1 pressure and temperature are shown in the box above the reactor)
- SG1
- Feed flow into main loop (kg/sec)
- P1 (selection allows 'START', 'STOP' and 'RESET' operations)
- Pressure (kPa) and temperature (°C) at the outlet of P1
- RIH1 (note that RIH1 pressure and temperature are shown in the box above the reactor)
- flow returns to fuel channel number 1

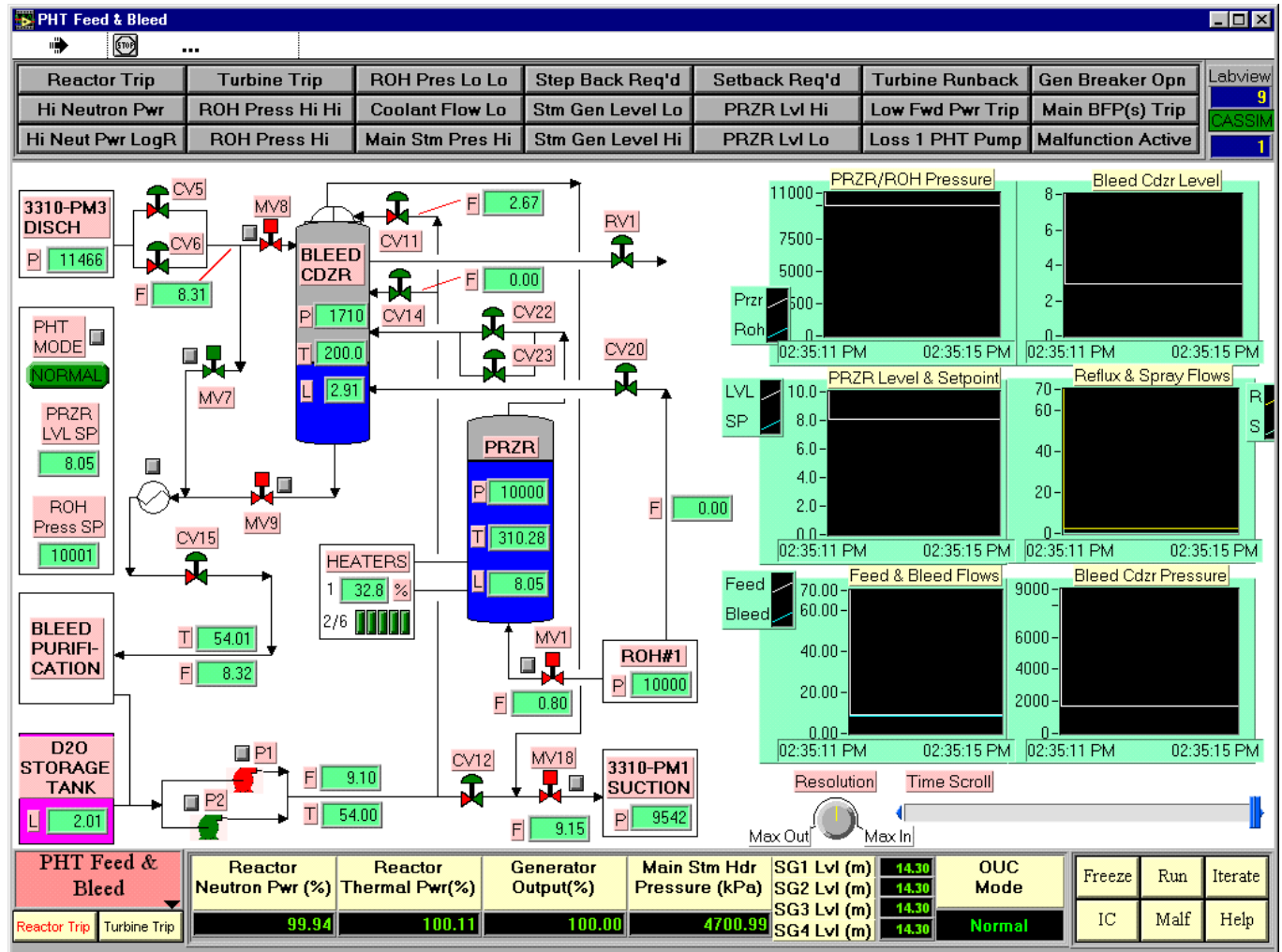
The same equipment and parameters are shown in the lower loop, except that instead of feed flow into this loop there is bleed flow out (kg/sec).



2.5 PHT FEED AND BLEED

This screen shows the Heat Transport pressure control system, including the pressurizer, bleed (or de-gasser) condenser, pressure relief, feed and bleed circuits and D2O storage tank.

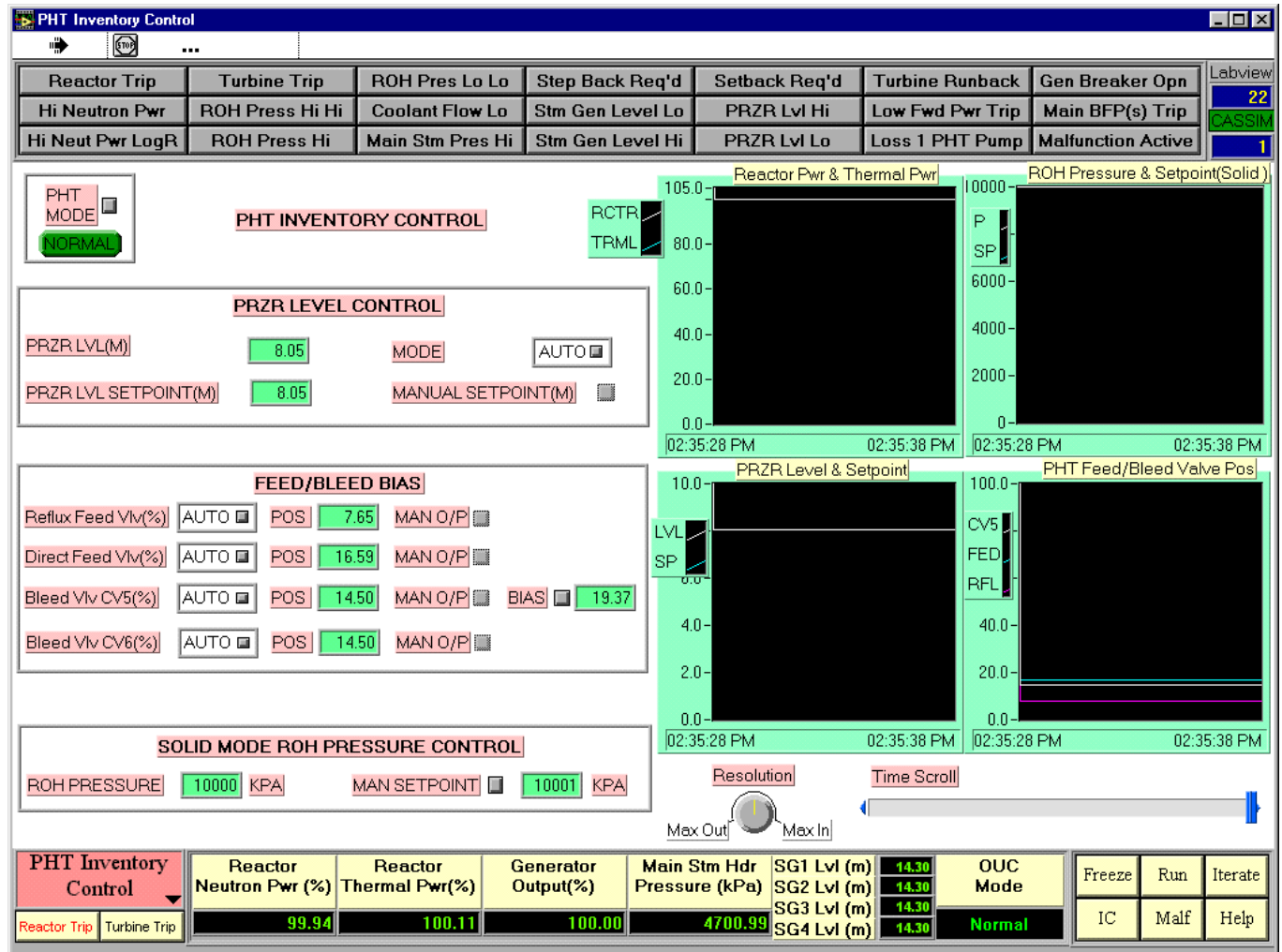
- Starting with the storage tank at the bottom left hand corner, its level is displayed in meters. The tank supplies the flow and suction pressure for the Feed (or Pressuring) pumps P1 and P2: normally one pump is running, the popup menu allows START, STOP and RESET operations.
- The Flow (kg/sec) and Temperature (°C) of the feed flow are displayed. Part of the flow goes to the Bleed Condenser to provide spray cooling (via CV14, kg/sec) and reflux cooling (via CV11, kg/sec), with the reflux flow being returned to the feed line past the feed control valve CV12; the feed flow then passes through the feed isolation valve MV18 before entering the main circuit at the suction of the main circulating pump 1.
- Proceeding in an anti-clockwise direction, the Pressure (kPa) and Temperature (°C) of ROH#1 are shown. Flow from the Outlet header is normally to and from the Pressurizer via MV1, a negative flow (kg/sec) indicating flow out of the pressurizer. In case of excessive heat transport header pressure, relief valve CV20 opens and discharges flow (kg/sec) to the Bleed Condenser. Pressurizer Pressure (kPa), Temperature(°C) and Level (m) are displayed.
- Pressurizer pressure is maintained by heaters (in case the pressure falls) and by steam discharge valves CV22 and CV23 if the pressure is too high.
- Bleed Condenser pressure relief is provided via RV1. Parameters displayed for the Bleed Condenser are: Pressure (kPa), Temperature(°C) and Level (m). Feed flow from main circuit pump 3 (header pressure in kPa) flows (kg/sec) via Bleed Control valves CV5, CV6 and MV8. Bleed Condenser by-pass is via MV7.
- The outflow from the Bleed Condenser is via MV9, the Bleed Cooler and the Bleed Condenser Level Control valve CV15 to the Purification Circuit. The values of Temperature(°C) and Flow (kg/sec) into the Purification System are displayed.
- Heat Transport pressure control in NORMAL mode is via the Pressurizer; via the PHT MODE popup menu SOLID mode can be selected. PRESSURIZER LEVEL SETPOINT and ROH PRESSURE SETPOINT are also shown.



2.6 PHT INVENTORY CONTROL

The screen shows the parameters relevant to controlling the inventory in the main heat transport loop. Either NORMAL or SOLID modes of operation may be selected. Note that in NORMAL mode, inventory control is achieved by controlling Pressurizer Level, while in SOLID mode inventory control is by means of maintaining main heat transport pressure via the feed and bleed valves.

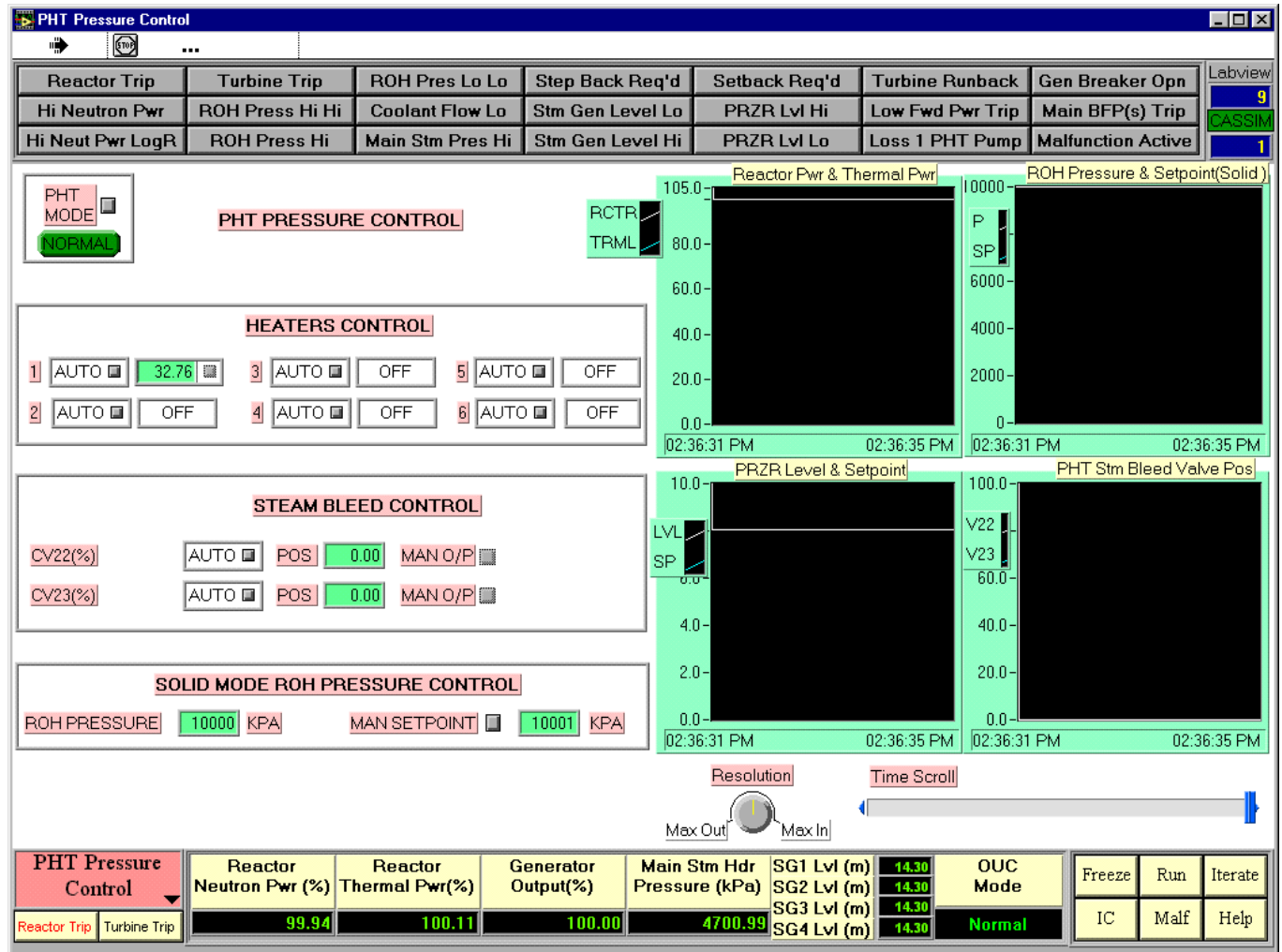
- Pressurizer Level is normally under computer control, with the setpoint being ramped as a function of reactor power and the expected shrink and swell resulting from the corresponding temperature changes. Level control may be transferred to MANUAL and the SETPOINT can then be controlled manually.
- The amount of feed and bleed is controlled about a bias value that is set to provide a steady flow of bleed to the Purification System. The amount of flow may be adjusted by changing the value of the BIAS. The positions of feed and bleed valves are normally under AUTO control, but may be changed to MANUAL using the popup menus.
- In SOLID mode the ROH PRESSURE (kPa) may be controlled manually via the popup menu.



2.7 PHT PRESSURE CONTROL

This screen is similar to the previous one in terms of the ability to select PHT Pressure Control MODE and SOLID MODE ROH PRESSURE CONTROL. The difference arise in the control of Pressurizer pressure.

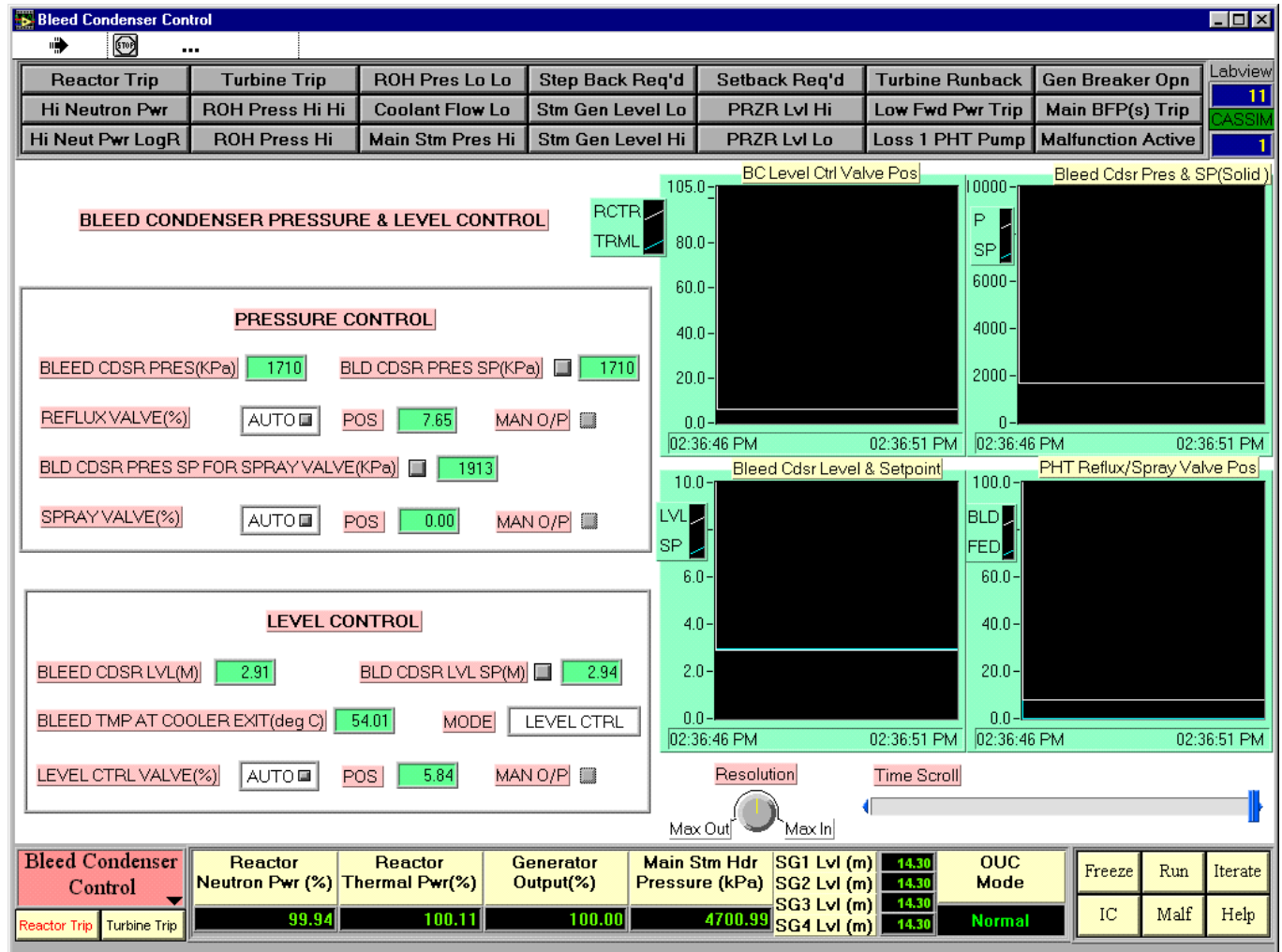
- The six HEATERS are normally in AUTO, with the variable Heater (#1) modulating. The other five heaters are either ON or OFF, and under AUTO control. Via the popup menus MANUAL operation can be selected, and each heater may be selected to START, STOP or RESET.
- STEAM BLEED CONTROL is via CV22 and CV23. These are normally in AUTO mode, but may be placed on MANUAL and the valve opening manually controlled via popup menus.



2.8 BLEED CONDENSER CONTROL

The parameters required to control Bleed Condenser Pressure and Level are shown on this screen.

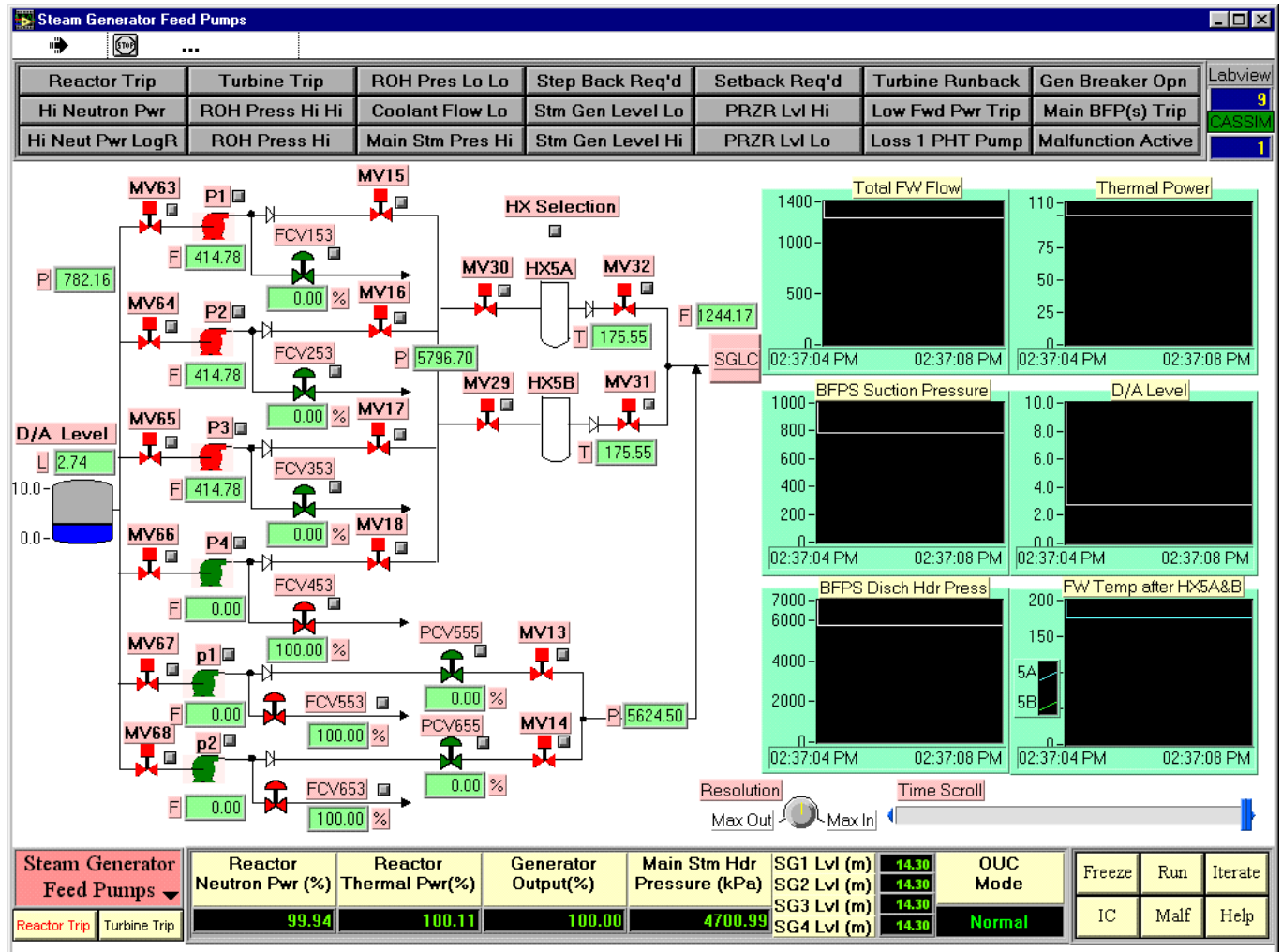
- PRESSURE CONTROL is normally achieved via altering the REFLUX flow, and SPRAY flow only takes place if REFLUX flow is unable to maintain pressure control. To achieve such a split mode of operation, the SETPOINT for the Reflux valve, denoted as BLEED CONDENSER PRESSURE SETPOINT (kPa) is set at a value lower than the BLEED CONDENSER PRESSURE SETPOINT FOR SPRAY VALVE (kPa). Both valves are normally on AUTO, but may be selected to MANUAL and the valve opening controlled directly via popup menus.
- LEVEL CONTROL is normally in the AUTO mode about the specified SETPOINT. However if the BLEED TEMPERATURE AT COOLER EXIT exceeds a preset value (68°C), the control mode is switched to TEMPERATURE CONTROL mode, which restricts the valve opening so as to protect the ion exchanger resin.
- The LEVEL CONTROL VALVE may be placed on MANUAL for direct control of the valve's position.



2.9 STEAM GENERATOR FEED PUMPS PAGE

Screen shows the portion of the feedwater system that includes the Deaerator, the boiler feed pumps, the high pressure heaters and associated valves, with the output of the HP heaters going to the Steam Generator Level Control Valves. The following parameters are displayed:

- Deaerator Level (m)
- Boiler Feedpump Suction Header Pressure (kPa)
- Boiler Feed Pump inlet valves (MV63 to MV68), outlet valves (MV13 to MV18) and associated popup menus allowing them to be opened or closed
- Main Boiler Feed Pumps (P1 to P4) and Auxiliary Boiler Feed Pumps p1 and p2 with associated popup menus for control selections
- Recirculating flow control valves FCV153, 253, 353, 453, 553, 653; pressure control valves PCV555, 565; and associated popup menus for AUTO/MANUAL selection and controller parameter tuning
- High Pressure Heaters HX5A and HX5B and popup menus to select either or both heaters to be in-service
- HP Heater isolation valves MV29 to MV32 and popup menus for open and close control
- Pressure at inlet and outlet of HP heaters (kPa)
- Flow at inlet header to Steam Generator Level Control Valves (kg/sec)

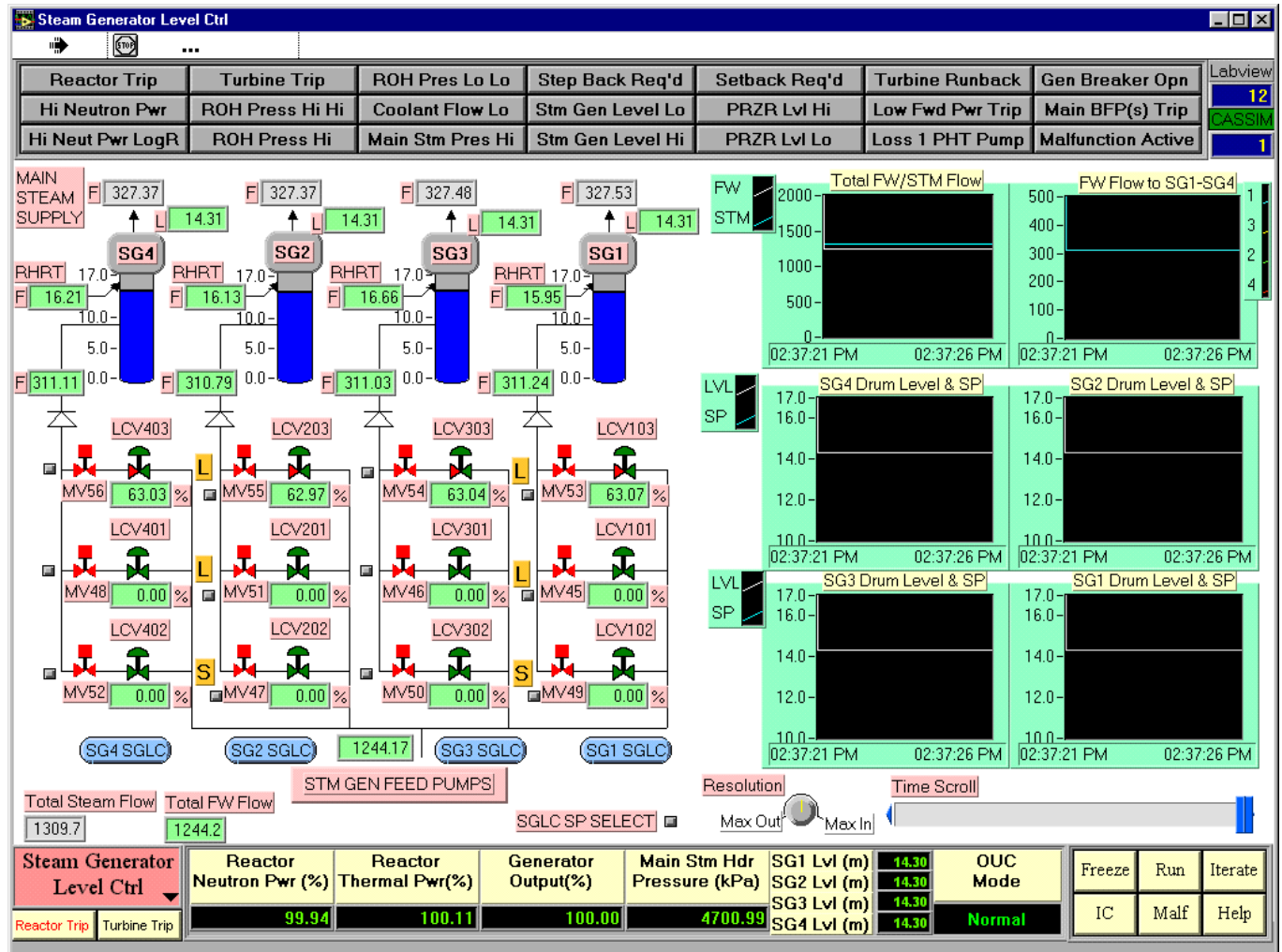


2.10 STEAM GENERATOR LEVEL CONTROL PAGE

Screen shows each of the four boilers and associated level control valves. The following parameters are described (starting near the top of the screen) for Steam Generator 1, the same applies to SG 2, 3 and 4.

- Steam Generator Flow (kg/sec)
- Steam Generator Level (m)
- Reheater Flow (kg/sec)
- Feedwater Flow (kg/sec)
- Large Level Control Valve (LCV103) Status and Opening (%)
- Large Level Control Isolation Motorized Valve (MV53) Status and AUTO/MANUAL Controller Popup Menu
- Large Level Control Valve (LCV101) Status and Opening (%)
- Large Level Control Isolation Motorized Valve (MV45) Status and AUTO/MANUAL Controller Popup Menu
- Small Level Control Valve (LCV102) Status and Opening (%)
- Small Level Control Isolation Motorized Valve (MV49) Status and AUTO/MANUAL Controller Popup Menu
- Steam Generator 1 Level Control (SG1 SGLC) Popup Menu
- Steam Generator Level Control Setpoint (SGLC SP) Select Popup Menu

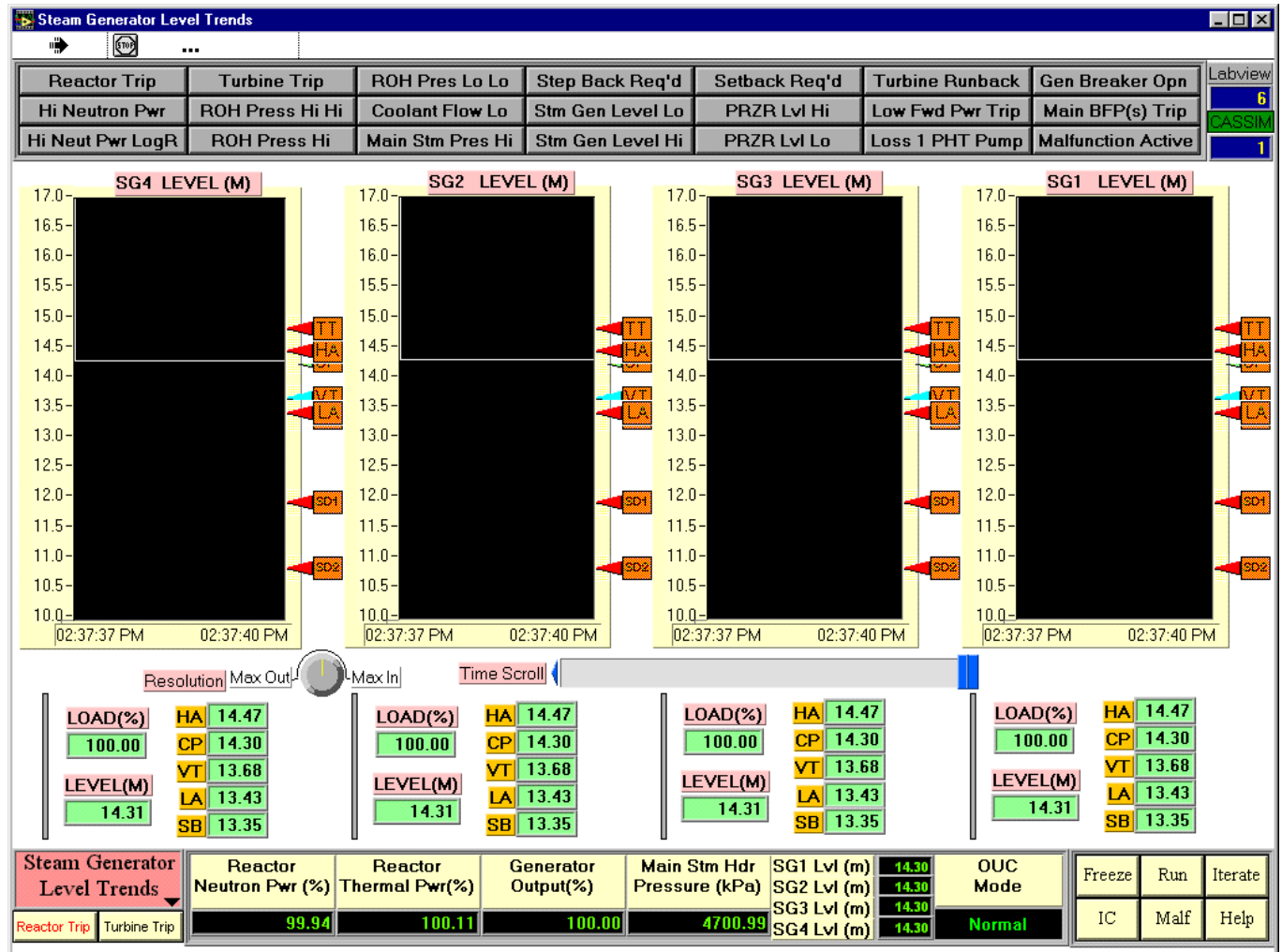
Total Steam Flow (kg/sec) and Total feedwater Flow (kg/sec) to all four Boilers is shown at the bottom left hand corner.



2.11 STEAM GENERATOR LEVEL TRENDS PAGE

Screen shows the steam generator level displays, including the actual level, the alarm, control and trip points. These points are identified as follows:

- TT - Turbine Trip
- HA - High steam generator level Alarm
- CP - Control (or set) Point
- VT - Valve Transfer Point
- LA - Low Steam generator level Alarm
- SB - SetBack reactor
- SDS1 - ShutDown System 1 trip
- SDS2 - ShutDown System 2 trip



2.12 STEAM GENERATOR LEVEL MANUAL CONTROL

- This screen allows the manual control of the level in each of the four steam generators. Since the actions are the same for any one steam generator, SG1 is the only one described here.
- Under normal operating conditions all level control valves are under DCC Control. At full power normally one large valve (LCV103 for SG1 at the 100%FP Initial Condition) is in control, the other large valve and the small valve are closed.
- While under DCC control the MAN O/P (Manual Output) station tracks the DCC signal.
- Transferring control from DCC to MANUAL allows direct control of the valve's position by the operator.
- For the small valves, transfer from DCC to AUTO allows for tuning of the controller, and valve control to be transferred from the DCC to either AUTO or MANUAL control.

Steam Generator Level Manual Ctrl								Labview
Reactor Trip	Turbine Trip	ROH Pres Lo Lo	Step Back Req'd	Setback Req'd	Turbine Runback	Gen Breaker Opn		6
Hi Neutron Pwr	ROH Press Hi Hi	Coolant Flow Lo	Stm Gen Level Lo	PRZR Lvl Hi	Low Fwd Pwr Trip	Main BFP(s) Trip		CASSIM
Hi Neut Pwr LogR	ROH Press Hi	Main Stm Pres Hi	Stm Gen Level Hi	PRZR Lvl Lo	Loss 1 PHT Pump	Malfunction Active		1

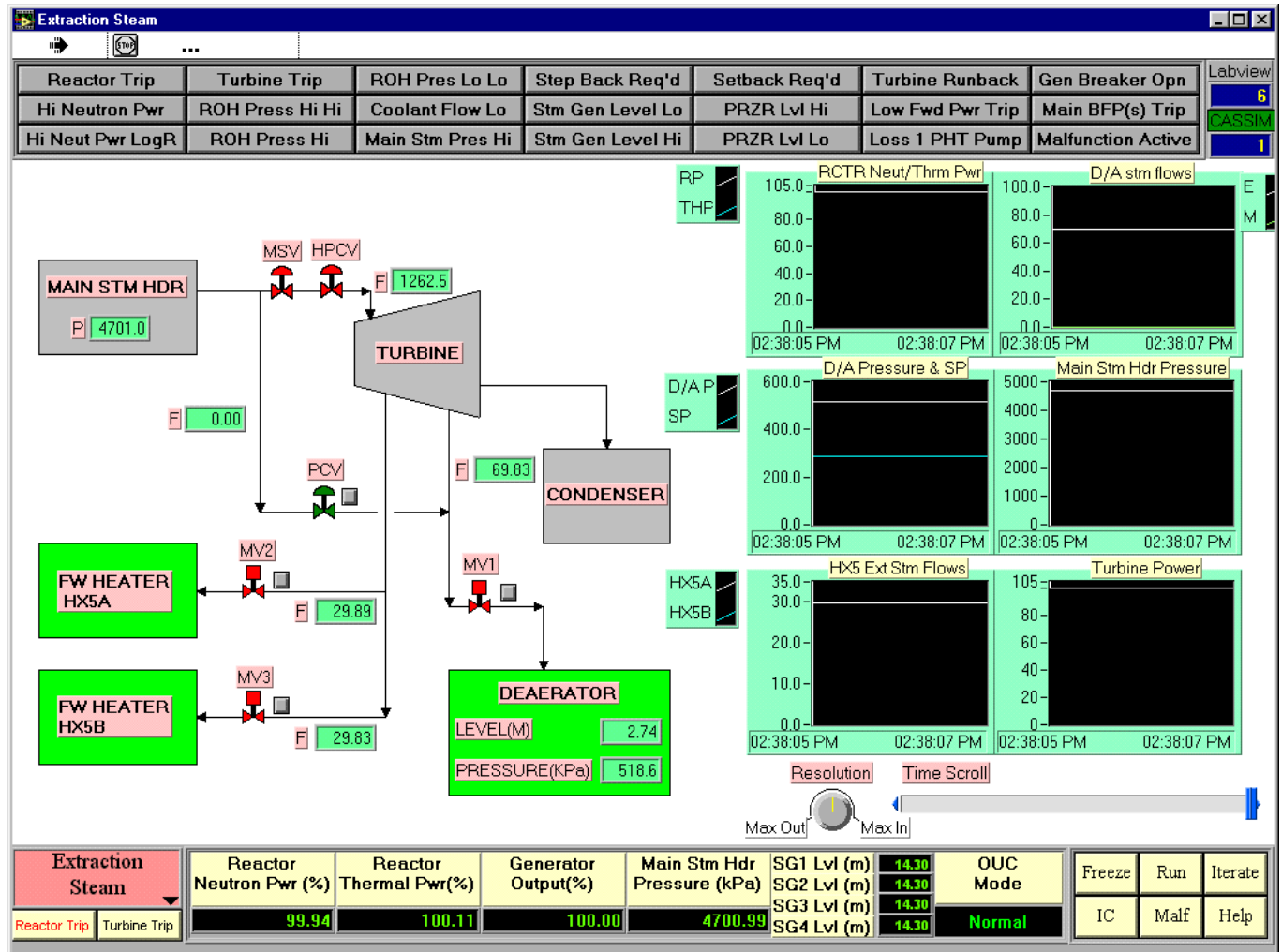
SG1	L LCV 103 VALVE(%)	DCC	POS	63.07	MAN O/P	
	L LCV 101 VALVE(%)	DCC	POS	0.00	MAN O/P	
	S LCV 102 VALVE(%)	DCC	POS	0.00	CONTROLLER	
SG3	L LCV 303 VALVE(%)	DCC	POS	63.04	MAN O/P	
	L LCV 301 VALVE(%)	DCC	POS	0.00	MAN O/P	
	S LCV 302 VALVE(%)	DCC	POS	0.00	CONTROLLER	
SG2	L LCV 203 VALVE(%)	DCC	POS	62.97	MAN O/P	
	L LCV 201 VALVE(%)	DCC	POS	0.00	MAN O/P	
	S LCV 202 VALVE(%)	DCC	POS	0.00	CONTROLLER	
SG4	L LCV 403 VALVE(%)	DCC	POS	63.03	MAN O/P	
	L LCV 401 VALVE(%)	DCC	POS	0.00	MAN O/P	
	S LCV 402 VALVE(%)	DCC	POS	0.00	CONTROLLER	

Steam Generator Lvl Man Ctrl	Reactor Neutron Pwr (%)	Reactor Thermal Pwr(%)	Generator Output(%)	Main Stm Hdr Pressure (kPa)	SG1 Lvl (m)	14.30	OUC Mode	Freeze	Run	Iterate
Reactor Trip	Turbine Trip	99.94	100.11	100.00	SG2 Lvl (m)	14.30	Normal	IC	Malf	Help
					SG3 Lvl (m)	14.30				
					SG4 Lvl (m)	14.30				

2.13 EXTRACTION STEAM PAGE

Screen shows the extraction steam flows from the Main Steam system to the Deaerator and the High Pressure Heaters in addition to the steam flow to the Turbine. The following parameters are displayed:

- Main Steam Header Pressure (MPa)
- Steam Flow to the Turbine (kg/sec)
- Steam flow to the Deaerator from the Main Steam Header (kg/sec)
- Extraction Steam flow to the Deaerator (kg/sec)
- Extraction Steam flow to the High Pressure Heaters (kg/sec)
- Deaerator Level (m)
- Deaerator Pressure (kPa)
- Valve Status for MSV (Motorized or Emergency Stop Valve) and HPCV (High Pressure Turbine Control or Governor Valve)
- Valve status and popup menus to provide for manual control of motorized valves MV1, 2 and 3
- Valve status and popup menu for AUTO/MANUAL selection and controller parameter tuning



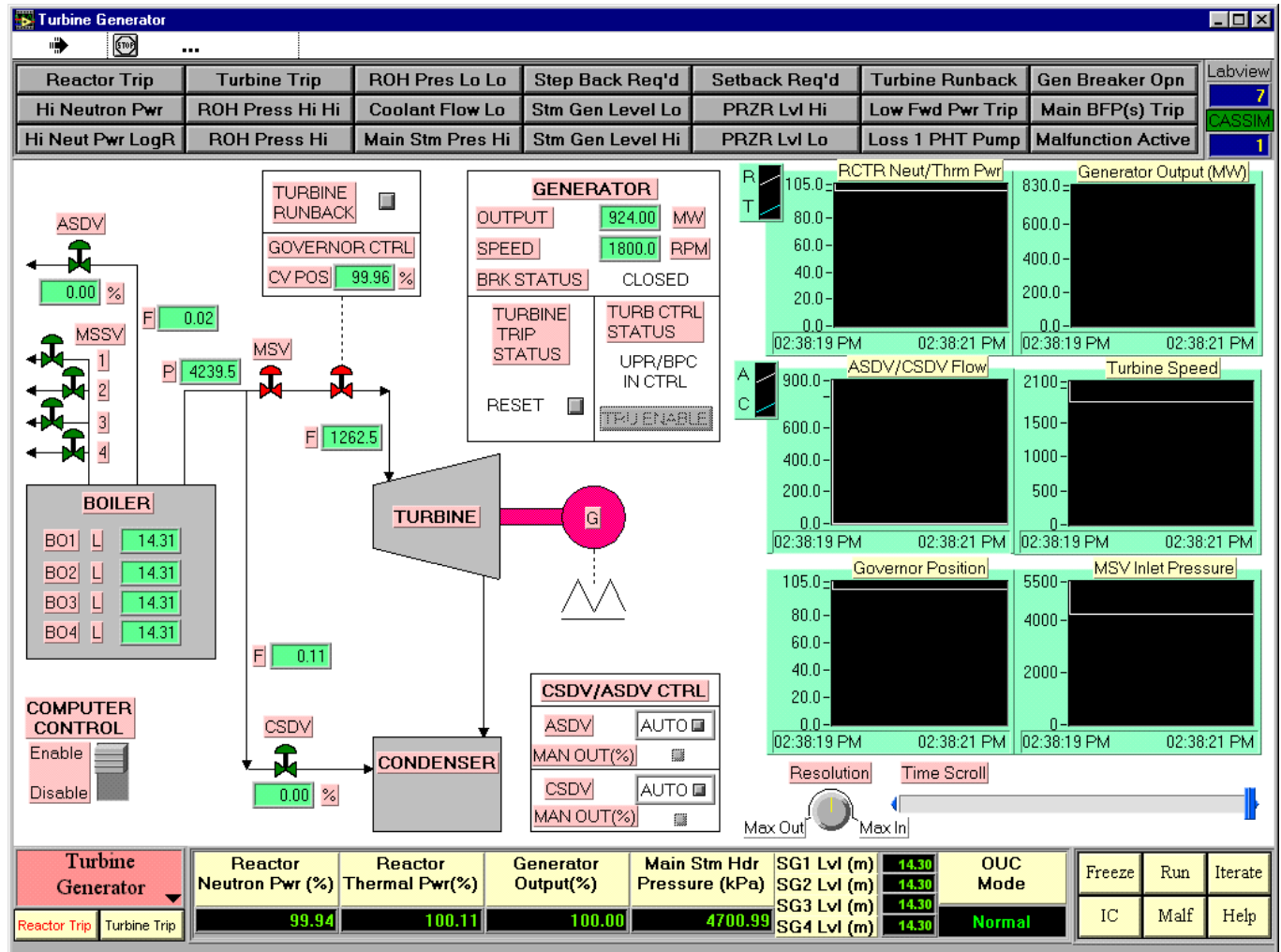
2.14 TURBINE GENERATOR PAGE

Shows the main parameters and controls associated with the Turbine and the generator. The parameters displayed are:

- Boiler 1, 2, 3, 4 Level (m)
- status of Main Steam Safety Valves (MSSV)
- status, opening and flow through the Atmospheric Steam Discharge Valves (ASDV) and the Condenser Steam Discharge Valves (CSDV)
- Steam Flow to the Turbine (kg/sec)
- Governor Control Valve Position (% open)
- Generator Output (MW)
- Turbine/Generator Speed of Rotation (rpm)
- Generator Breaker Trip Status
- Turbine Trip Status
- Turbine Control Status
- All the trend displays have been covered elsewhere or are self explanatory

The following pop-up menus are provided:

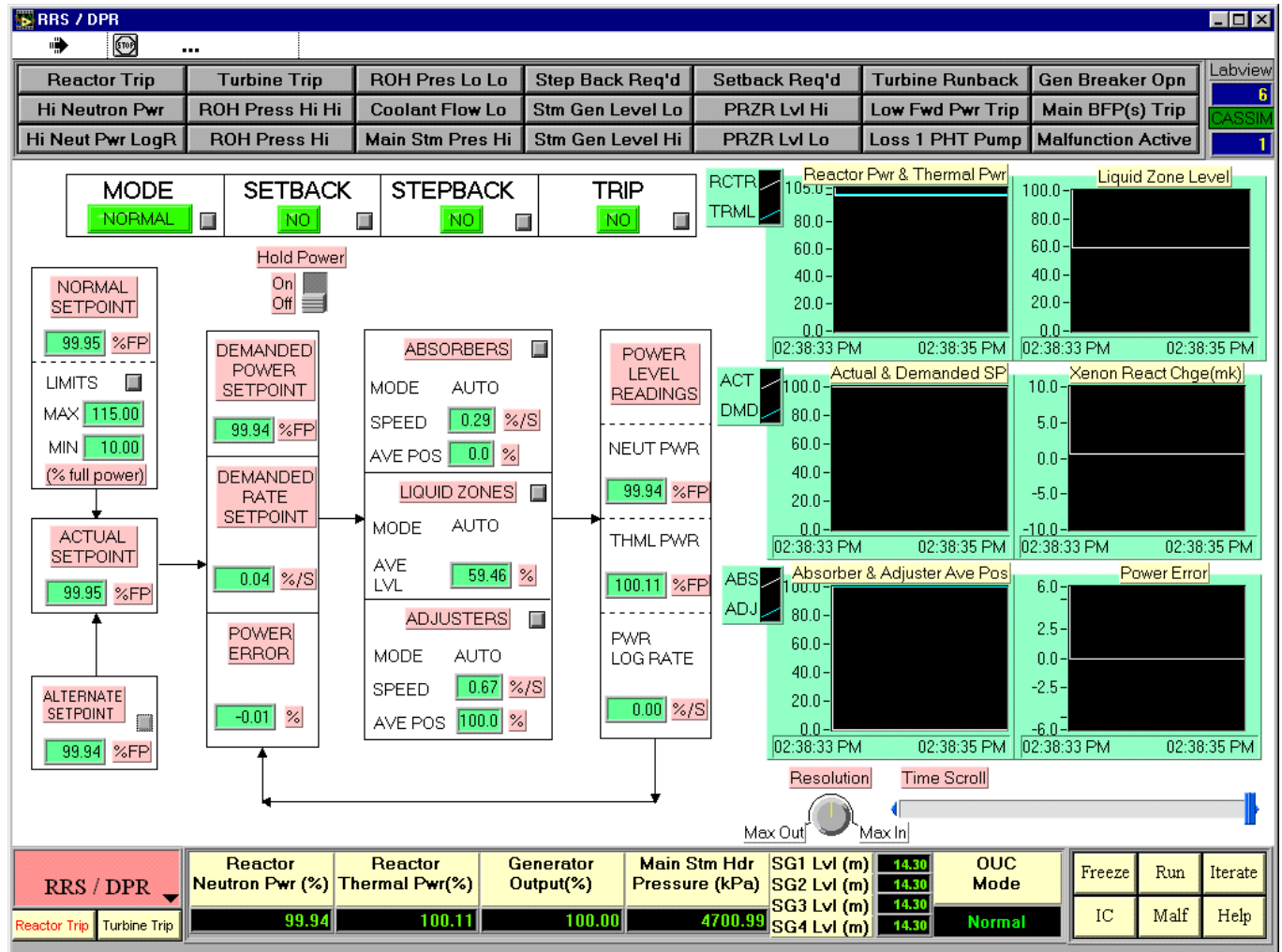
- TURBINE RUNBACK - sets Target (%) and Rate (%/sec) of runback when 'Accept' is selected
- TURBINE TRIP STATUS - Trip or Reset
- ASDV and CSDV AUTO/MANUAL Control - AUTO Select, following which the Manual Position of the valve may be set



2.15 RRS / DPR PAGE

This screen permits control of reactor power setpoint and its rate of change while under Reactor Regulating System (RRS) control, i.e. in 'alternate' mode. Several of the parameters key to RRS operation are displayed on this page.

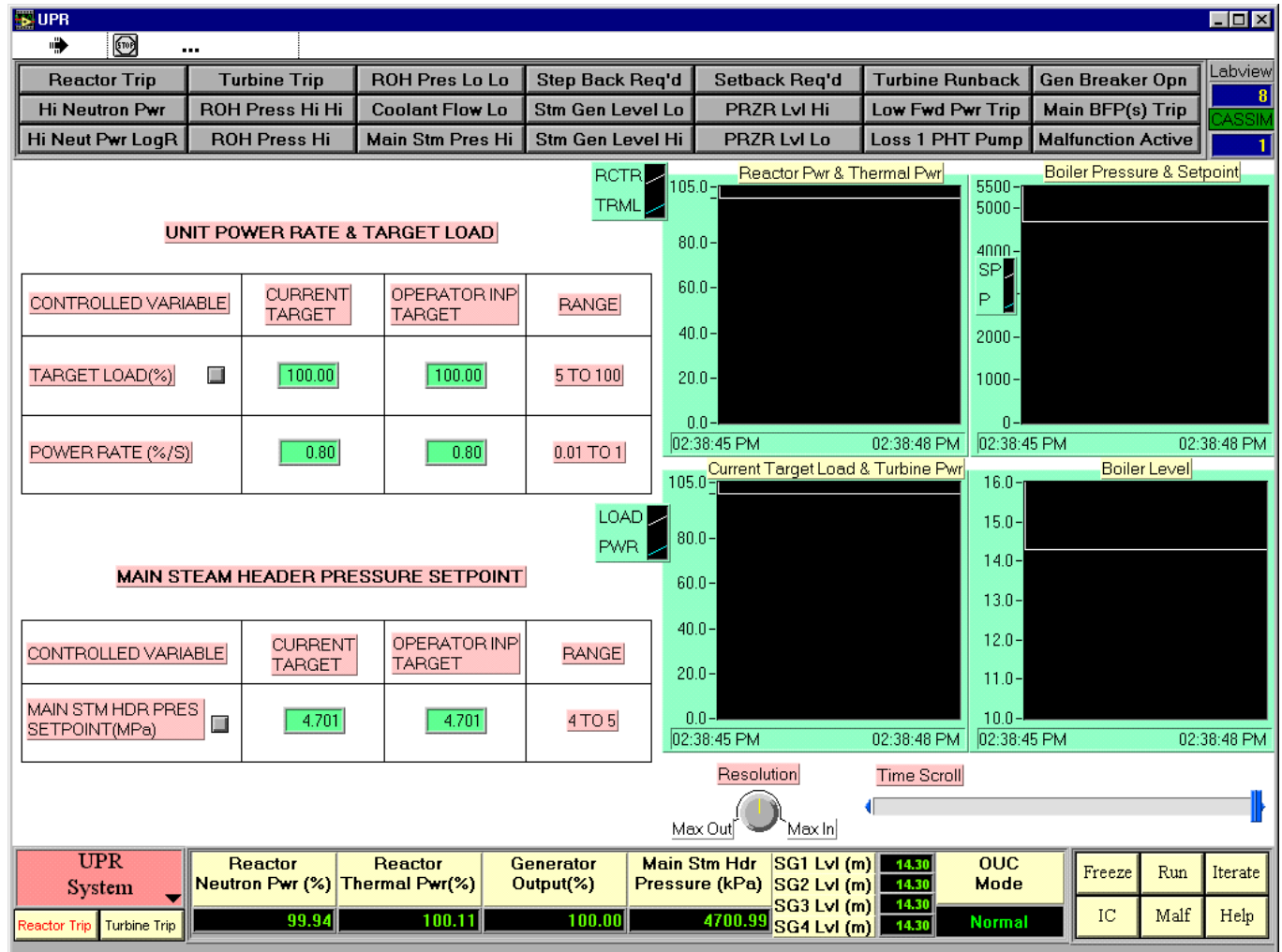
- The status of reactor control is indicated by the four blocks marked MODE, SETBACK, STEPBACK AND TRIP. They are normally green but will turn yellow when in the abnormal state.
 - ⇒ MODE will indicate whether the reactor is under NORMAL to ALTERNATE control, this status can also be changed here.
 - ⇒ SETBACK status is indicated by YES or NO; Setback is initiated automatically under the prescribed conditions by RRS, but at times the operator needs to initiate a manual Setback, which is done from this page on the Simulator: the Target value (%) and Rate (%/sec) need to be input.
 - ⇒ STEPBACK status is indicated by YES or NO; Stepback is initiated automatically under the prescribed conditions by RRS, but at times the operator needs to initiate a manual Stepback, which is done from this page on the Simulator: the Target value (%) need to be input.
 - ⇒ TRIP status is indicated by YES or NO; trip is initiated by the Shutdown Systems, if the condition clears, it can be reset from here. Note however, that the tripped SDS#1 must also be reset before RRS will pull out the shutdown rods, this must be done on the Shutdown Rods Page
- Key components of RRS and DPR control algorithm are also shown on this screen.
 - ⇒ The ACTUAL SETPOINT is set equal to the NORMAL SETPOINT under UPR control ('normal mode'), the upper and lower limits on this setpoint can be specified here.
 - ⇒ The ACTUAL SETPOINT is set equal to the ALTERNATE SETPOINT under RRS control ('alternate mode'); the value of ALTERNATE SETPOINT is input on this page.
 - ⇒ Operation of HOLD POWER while in 'normal mode' selects 'alternate mode' and sets DEMANDED POWER SETPOINT equal to the measured Neutron Power. However, in 'alternate mode' it does not respond as it should.
 - ⇒ The computed values of DEMANDED POWER SETPOINT, DEMANDED RATE SETPOINT and POWER ERROR are shown on this page, both on the block diagram and on the trend plots.
 - ⇒ The Absorbers, the Liquid Zones and the Adjusters can be placed on Manual, but no manual operation of these devices is possible on this page.
 - ⇒ Neutron Power, and Thermal are displayed as part of the block diagram, these readings are the same as at the bottom of each page. However, PWR LOG RATE can only be observed on this page.



2.16 UPR PAGE

This screen permits control of station load setpoint and its rate of change while under Unit Power Regulator (UPR) control, i.e. 'normal' mode. Control of the Main Steam Header Pressure is also through this screen, but this is not usually changed under normal operating conditions.

- OUC (overall Unit Control) MODE can be changed from NORMAL to ALTERNATE.
- TARGET LOAD - on selection Station Load (%) and Rate of Change (%/sec) can be specified; change becomes effective when 'Accept' is selected.
 - ⇒ The OPERATOR INP TARGET is the desired setpoint inserted by the operator; the CURRENT TARGET will be changed at a POWER RATE specified by the operator.
 - ⇒ Note that the RANGE is only an advisory comment, numbers outside the indicated range of values may be input on the Simulator.
- MAIN STEAM HEADER PRESSURE SETPOINT (MPa) - alters the setpoint, which is rarely done during power operation. Caution must be exercised when using this feature on the Simulator, since the requested change takes place in a step fashion as soon as the change is made; changes should be made in increments of 0.1 MPa.



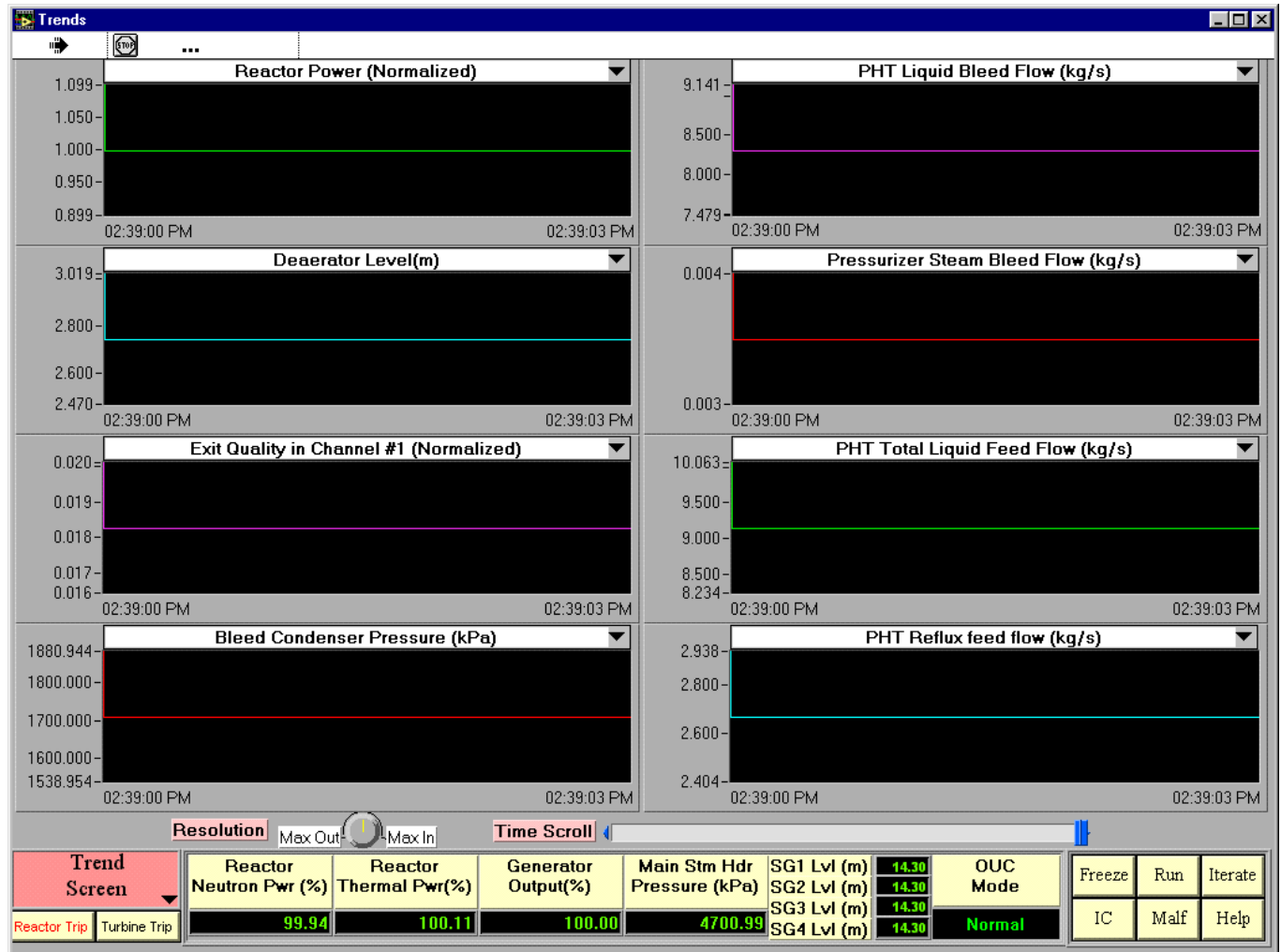
2.17 TREND

This screen shows the trend plots for eight simulated plant parameters. The list below gives the parameter names that may be selected for plotting on any one of the eight trend displays. The list can be displayed by pointing to the black triangle at the top right hand corner of the selected plot, holding down the left mouse button and highlighting the desired parameter.

Note that the vertical axis on each plot has its scale adjusted automatically to correspond to the maximum and minimum values of the parameter during the time segment indicated by the horizontal axis.

This trend feature should be used whenever parameters from different systems need to be viewed on the one display, and none of the other pages has the required combination of parameters.

Reactor Power (Normalized)	PHT Liquid Relief Flow (kg/s)
Total Delta mK (mK)	Bleed Condenser Spray Flow (kg/s)
Xenon Load (mK)	Bleed Condenser Pressure (kPa)
Thermal Power Release In Nuclear Fuel (Normalized)	Bleed Condenser Level (m)
RIH#1 Coolant Temp (Deg C)	Bleed Cooler Outlet Temp (Deg C)
RIH#2 Coolant Temp (Deg C)	Bleed Condenser Outlet Flow (kg/s)
RIH#3 Coolant Temp (Deg C)	Deaerator Pressure (kPa)
RIH#4 Coolant Temp (Deg C)	Deaerator Level (m)
ROH#1 Coolant Temp (Deg C)	Main Stm to Deaerator PCV Pos (Norm)
ROH#2 Coolant Temp (Deg C)	Ave Temp of Feedwater at HPHX Outlet (Deg C)
ROH#1 Pressure (kPa)	Feed water Flow to Boiler#1 (kg/s)
ROH#2 Pressure (kPa)	Feed water Flow to Boiler# 2(kg/s)
RIH#1 Pressure (kPa)	Feed water Flow to Boiler#3 (kg/s)
RIH#2 Pressure (kPa)	Feed water Flow to Boiler#4 (kg/s)
RIH#3 Pressure (kPa)	Boiler#1 Drum Level (m)
RIH#4 Pressure (kPa)	Boiler#2 Drum Level (m)
Measured Reactor Thermal Power (Normalized)	Boiler#3 Drum Level (m)
Coolant Flow Rate to Quadrant 1 (kg/s)	Boiler#4 Drum Level (m)
Coolant Flow Rate to Quadrant 2 (kg/s)	Boiler#1 Drum Level Set Point (m)
Coolant Flow Rate to Quadrant 3 (kg/s)	Boiler#2 Drum Level Set Point (m)
Coolant Flow Rate to Quadrant 4 (kg/s)	Boiler#3 Drum Level Set Point (m)
Exit Quality in Channel #1 (Normalized)	Boiler#4 Drum Level Set Point (m)
Exit Quality in Channel #2 (Normalized)	Main Steam Header Temp(Deg C)
Exit Quality in Channel #3 (Normalized)	Main Steam Header Pressure (kPa)
Exit Quality in Channel #4 (Normalized)	Pressure at MSV inlet (kPa)
Pressurizer Pressure (kPa)	Steam Flow through ASDV (kg/s)
Pressurizer Temperature (Deg C)	Steam Flow through CSDV (kg/s)
Pressurizer Level (m)	Total Steam Flow through Relief Valves (kg/s)
Pressurizer Level Set Point (m)	Total Steam Flow from Boiler (kg/s)
PHT Liquid Bleed Flow (kg/s)	Steam Flow to Turbine (kg/s)
PHT Total Liquid Feed Flow (kg/s)	Turbine Mechanical Power (Normalized)
PHT Reflux feed flow (kg/s)	Turbine Gross Electrical Power (Normalized)
	Turbine Speed (RPM)



CANDU-9 COMPACT SIMULATOR

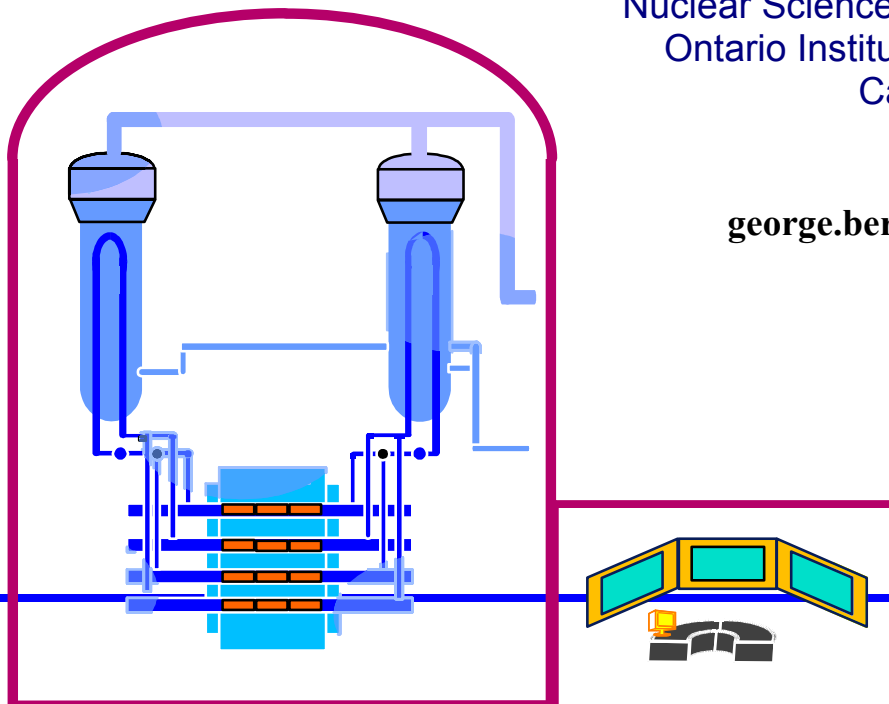
EXERCISES

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1. OVERALL UNIT CONTROL

1.1 POWER MANEUVER: 10% Power Reduction and Return to Full Power

- (1) Initialize Simulator to 100% full power;
- (2) verify that all parameters are consistent with full power operation;
- (3) select the UPR page, and change the scale on the "Reactor Pwr & Thermal Pwr" and "Current Target Load & Turbine Pwr" graphs to be between 80 and 110 percent, the "Main Steam Hdr Pressure & SP" to 4500 and 5000 kPa, "Boiler Level" to 13 and 15 meters, and set "Resolution" to "Max Out";
- (4) reduce unit power in the 'normal' mode, i.e.
 - using the UPR display
 - select 'TARGET LOAD (%)' pop-up menu
 - in pop-up menu lower 'target' to 90.00% at a 'Rate' of 1.0 %/sec
 - 'Accept' and 'Return'
- (5) observe the response of the displayed parameters until the transients in Reactor Power and Steam Pressure are completed (approximately 4 minutes and full time scale on the graph) without freezing the Simulator and/or stopping Labview, and explain the main changes;
- (6) continuing the above operation, raise "UNIT POWER" to 100% at a rate of 1.0%FP/sec.

ASSIGNMENT:

- (a) What is the maximum value of Steam Generator Pressure during the above set of maneuvers and at what stage of the transients does it occur?
- (b) What is the minimum value of Steam Generator Pressure during the above set of maneuvers and at what stage of the transients does it occur?
- (c) Is the turbine leading the reactor or the reactor leading the turbine in the above transients? Please explain on what parameter observations do you base your answer.

1.2 RESPONSE TO POWER MANEUVER (NORMAL MODE)

- Initialize the Simulator to 100%FP, reduce power using UPR in 25% steps at 0.5%/sec (trip the reactor for the 0% state) and record the following values:

Parameter	Unit	100%	75%	50%	25%	0%	Comments
Reactor Power	%						
ROH Pressure	MPa						
ROH Temperature	°C						
RIH Pressure	MPa						
RIH Temperature	°C						
Pressurizer Level	m						
HT Pump Flow	Mg/s						
Boiler Pressure	MPa						
Boiler Temperature	°C						
Boiler Level	m						
Steam Flow	kg/s						
Feedwater Flow	kg/s						
Turbine-Generator Power	%						

ASSIGNMENT:

Under “Comments” please note the type of parameter change as a function of reactor power 0% → 100%FP: constant, linear increase or decrease, non-linear increase or decrease.

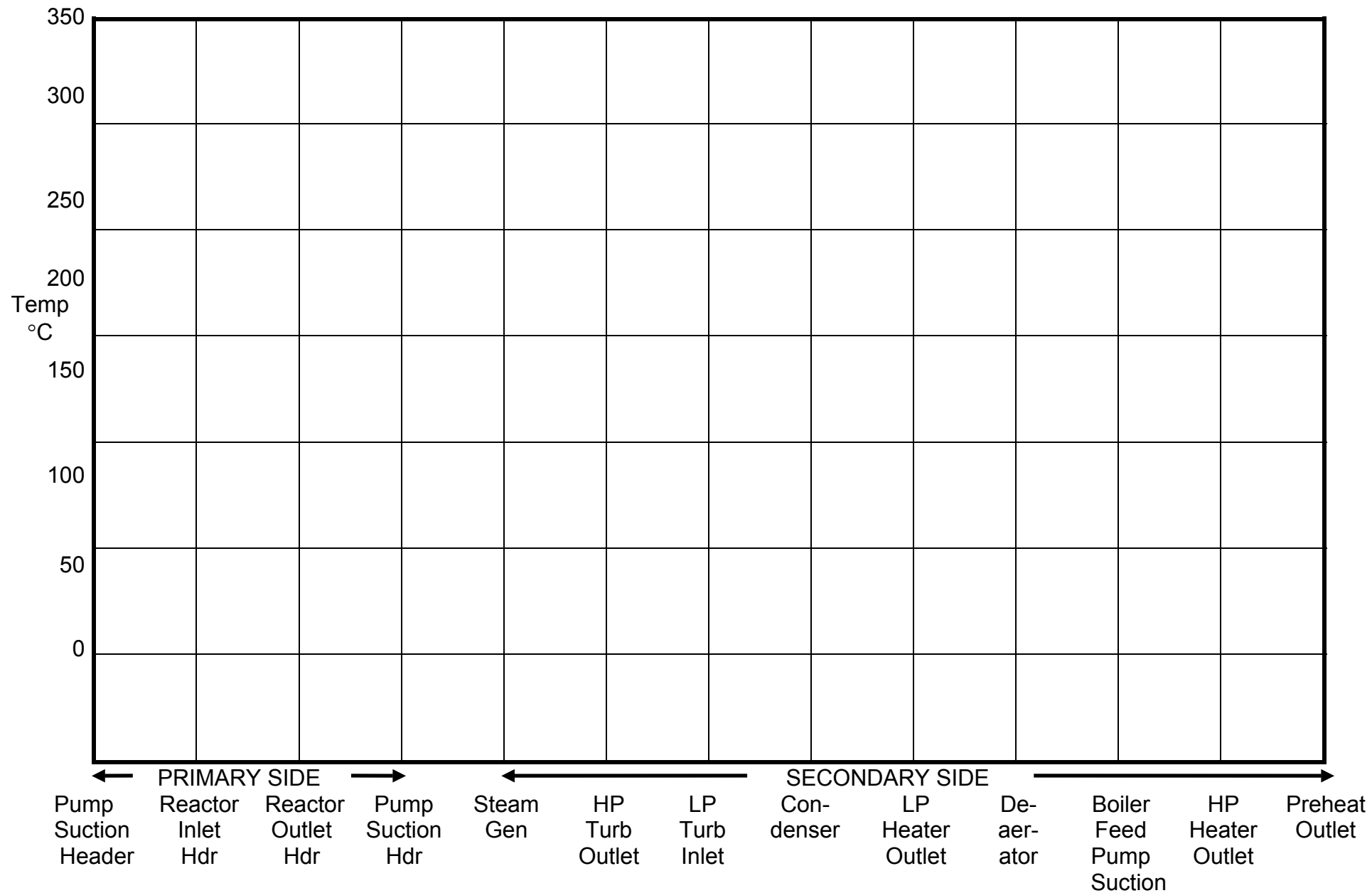
1.3 TEMPERATURE PROFILE ACROSS A CANDU 9 UNIT AT FULL POWER

- (1) Initialize the Simulator to 100% Full Power;
- (2) record the missing values of the parameters in the table below.

Station Equipment	Pressure (kPa)	Temperature (°C)
Reactor Inlet Header		
Reactor Outlet Header		
Steam Generator		
HP Turbine Exhaust	900	170
LP Turbine Inlet	900	230
Condenser	5	35
LP Heater Outlet	700	100
Deaerator		130
Boiler Feedpump Inlet		
HP Heater Outlet		
Preheater Outlet		

ASSIGNMENT:

Plot these parameters on the attached grid.



2. REACTOR REGULATING SYSTEM OPERATION

2.1 POWER MANEUVER IN 'ALTERNATE' MODE

- (1) Initialize the Simulator to 100%FP, select 'ALTERNATE MODE", and record parameter values in column (1);
- (2) reduce power using RRS to 50% at 0.5%/sec, observe parameter changes during transient, freeze the Simulator as soon as Reactor Neutron Power reaches 50% and record parameter values column (2);
- (3) unfreeze and let parameters stabilize, record parameter values column (3);
- (4) return reactor power to 100%FP at 0.5%/sec, freeze as soon as Reactor Neutron Power reaches 100% and record parameter values column (4);
- (5) unfreeze and let parameters stabilize, record parameter values column (5).

Parameter	Unit	(1) 100%	(2) 50%	(3) 50%	(4) 100%	(5) 100%	Comments
Reactor Neutron Power	%						
Reactor Thermal Power	%						
Average Zone Level	%						
Actual Setpoint	%						
Demanded Power Setpoint	%						
Demanded Rate Setpoint	%/sec						
Power Error	%						
Boiler Pressure	MPa						
Boiler Temperature	°C						
Boiler Level	m						
Steam Flow	kg/s						
Feedwater Flow	kg/s						
Governor valve opening	%						
Turbine-Generator Power	%						

ASSIGNMENT:

(a) Explain the changes in Average Zone Level between each operating state (column):

- (1) → (2)

- (2) → (3)

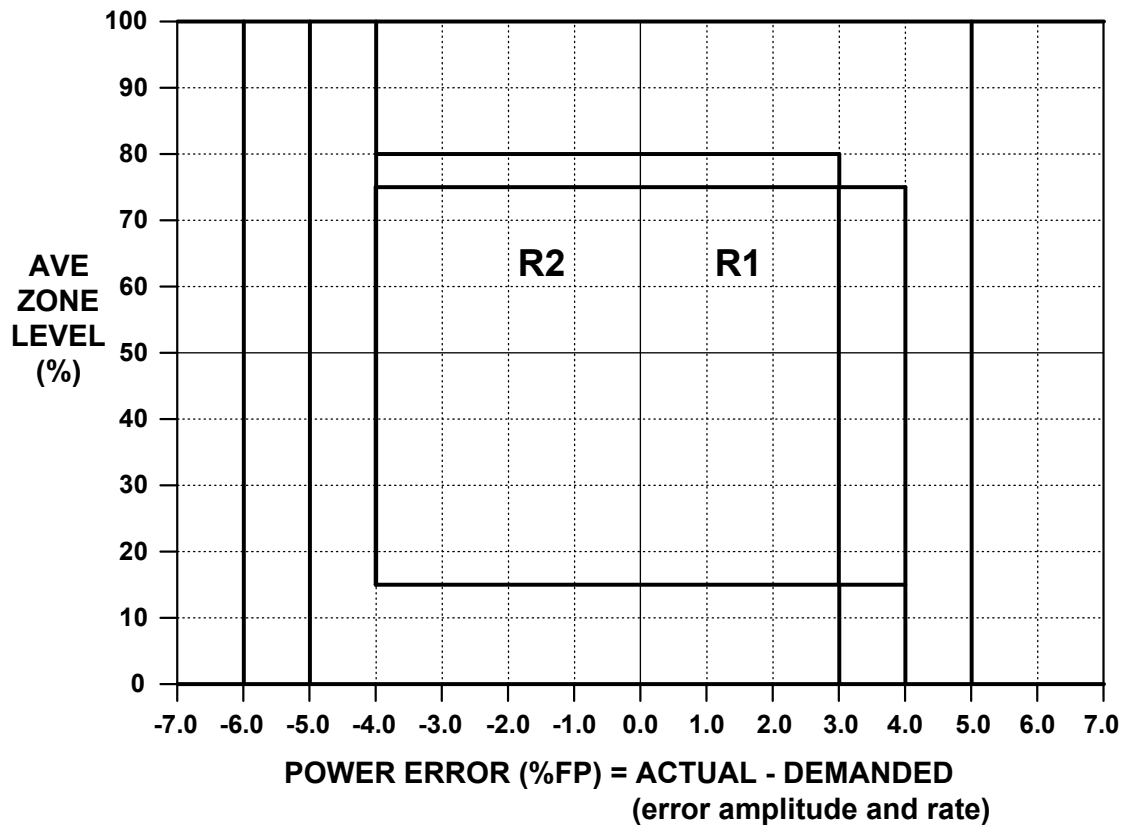
- (3) → (4)

- (4) → (5)

(b) In Column (2) Reactor Neutron Power is much lower than Turbine-Generator Power. Where is the extra energy coming from?

2.2 RESPONSE OF RRS CONTROL ALGORITHM TO POWER MANEUVER

- (1) Initialize the Simulator to 100%FP and from the Reactivity Control page note the position of the operating point on the attached diagram (confirm the value of Average Zone Level on the Plant Overview page);
- (2) insert a power reduction request using RRS to 70%FP at 0.8%/sec and freeze the simulator (remember that “ALTERNATE MODE” must be selected if power level change is to be requested via RRS);
- (3) go to the Reactivity Control page, unfreeze, and note the path of the operating point on the attached diagram, until power error has stabilized at or near zero (about 3 - 4 minutes);
- (4) confirm the value of average zone level on the Plant Overview page.



ASSIGNMENT:

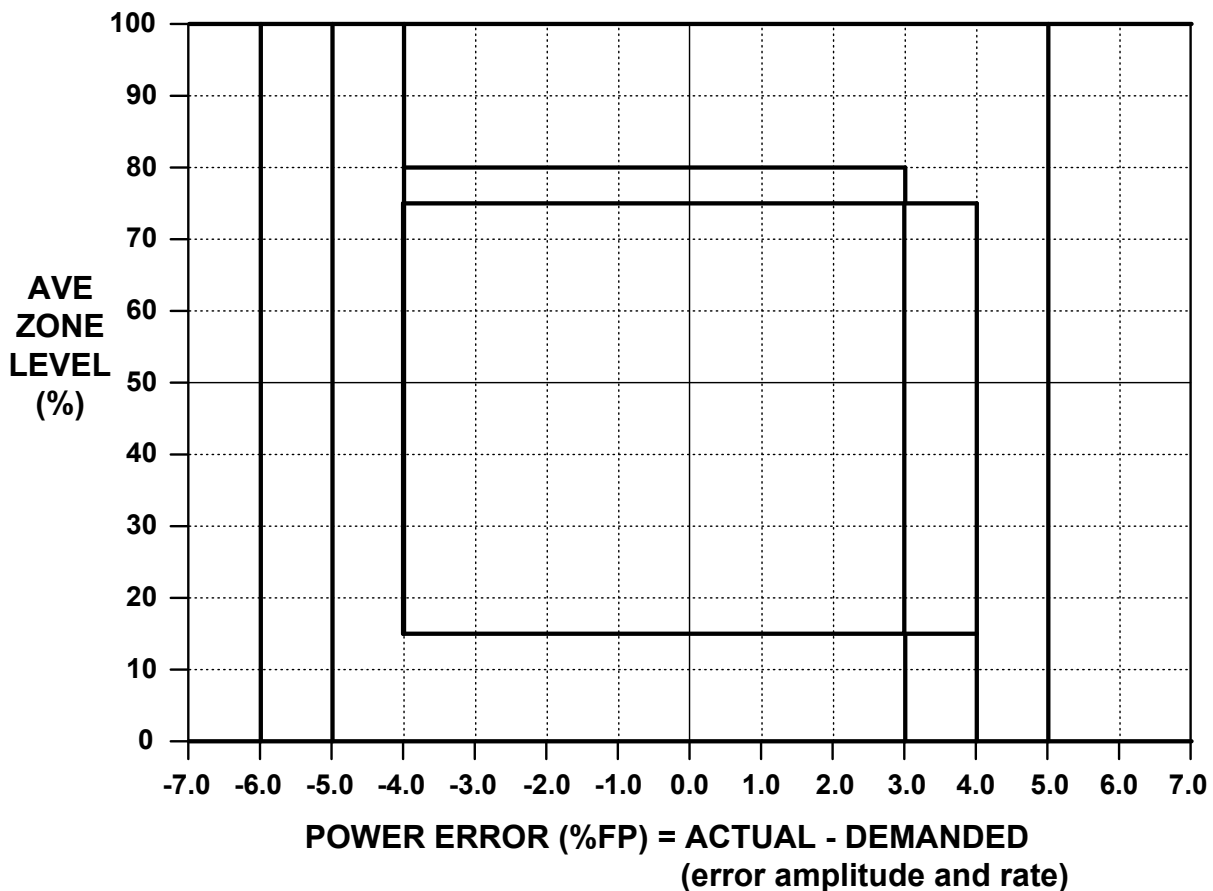
(a) Why does the operating point start out in Region R1, then go to Region R2?

(b) What is the final value of the average zone level?
final zone level higher than the original zone level?

Why is the

2.3 REACTOR AND RRS RESPONSE TO POWER MANEUVER

- (1) Initialize the Simulator to 100%FP and from the Reactivity Control page note the position of the operating point on the attached diagram;
- (2) insert a power reduction request using RRS to 10%FP at 0.8%/sec and freeze the simulator;
- (3) go to the Reactivity Control page, unfreeze, and note the path of the operating point on the attached diagram, until at least one Adjuster Rod bank is out of the reactor (about 20 minutes) - once the first Adjuster Bank is more than 50% withdrawn, place Absorbers on Manual and drive them fully OUT.



ASSIGNMENT:

- (a) Compare the response to case 2.2 and explain the main differences, particularly the 'end' state.
- (b) Explain what would happen to the reactor if the setpoint remained at 10%FP for several hours.

2.4 POWER MANEUVER UNDER MANUAL CONTROL

- (1) Initialize the Simulator to 100%FP and select ALTERNATE MODE. On the Reactivity Control page place the controllers for LIQUID ZONE, ABSORBERS and ADJUSTERS on MANUAL. Do not use liquid zone control during this exercise;
- (2) using Absorber and Adjuster drives on Manual, maneuver reactor power so as to reduce generator power to a level between $80 \pm 1\%$ FP and Main Stm Header Pressur between 4700 ± 50 kPa (if the CSDVs open, place them on MANUAL and keep them closed).

ASSIGNMENT:

- (a) Note the time taken from the start of lowering reactor power until steady operation within the specified error limits is achieved as compared with a power reduction rate of 0.5%FP/sec;
- (b) note any difficulties in controlling the unit.

2.5 MANUAL WITHDRAWAL OF ADJUSTER RODS

- (1) Initialize the Simulator to 100%FP and select ALTERNATE MODE. On the Reactivity Control page place the controllers for LIQUID ZONE, ABSORBERS and ADJUSTERS on MANUAL. Do not use liquid zone control during this exercise;
- (2) manually withdraw the Adjuster rods.

ASSIGNMENT:

Describe and explain the response of the Reactor and related systems.

3. REACTOR REGULATING SYSTEM MALFUNCTIONS AND TRIPS

3.1 FAIL OPEN LIQUID ZONE INLET VALVES

- (1) Initialize the Simulator to 100%FP, select ALTERNATE MODE and go to the Reactivity Control page;
- (2) place LIQUID ZONE controller on MANUAL and select Control Valve Position Manual Output to 100%;
- (3) record the following data:

Time (min)	0	0.5	1	2	4	6	8	10
Average Zone Level (%)								
Reactor Neutron Power (%FP)								
Reactor Power Error (%)								
Generator Output (%FP)								

ASSIGNMENT:

- (a) What happens to Reactor Neutron Power and how the Reactor Regulating responds?
- (b) Explain why reactor power oscillates after the initial transient is over?
- (c) What should the operator do to stop the oscillations in reactor power?

3.2 FAIL CLOSED LIQUID ZONE INLET VALVES

- (1) Initialize the Simulator to 100%FP, select ALTERNATE MODE, and go to the Reactivity Control page;
- (2) place LIQUID ZONE controller on MANUAL and select Control Valve Position Manual Output to 0%;
- (3) record the following data:

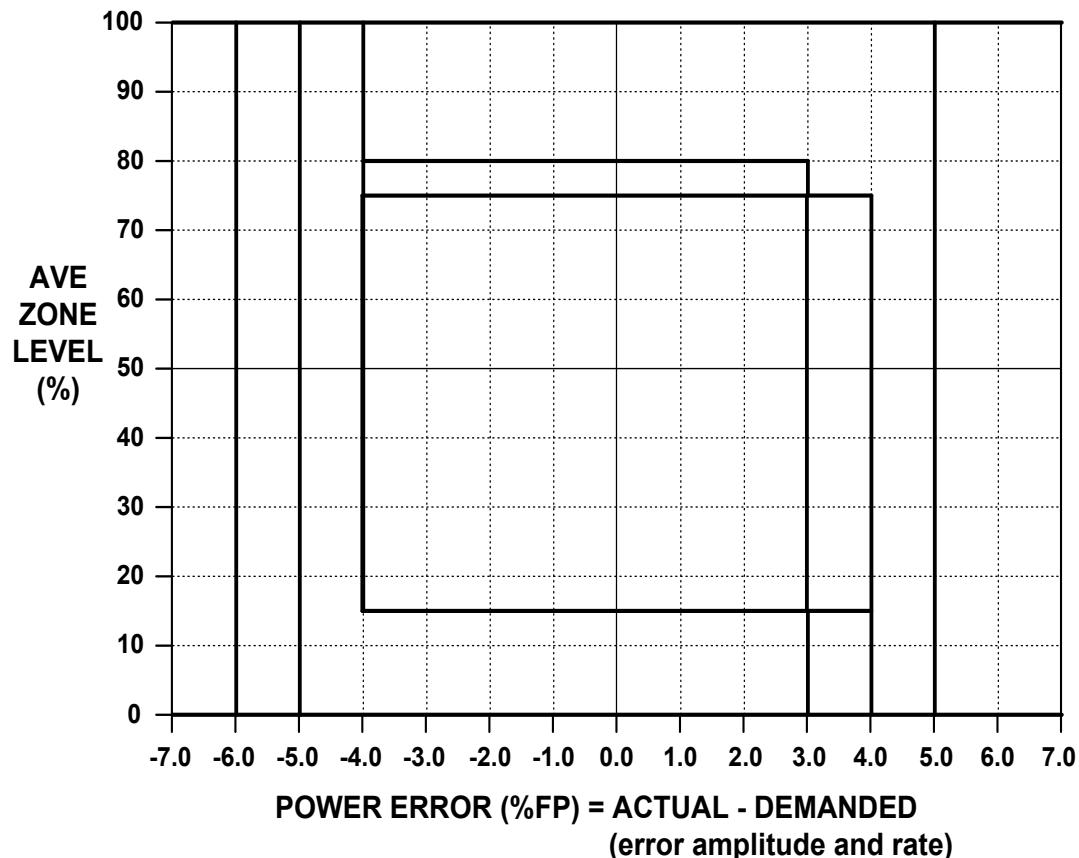
Time (sec)	0	10	20	30	40	50	60	120
Average Zone Level (%)								
Reactor Neutron Power (%FP)								
Reactor Power Error (%)								
Generator Output (%FP)								

ASSIGNMENT:

- (a) Describe the responses of the Reactor and Reactor Regulating System.
- (b) Explain the differences between Exercise 3-1 and 3-2, noting the difference in reactor physics response.
- (c) Why does the reactor trip?

3.3 ONE BANK OF ABSORBER RODS DROP

- (1) Initialize the Simulator to 100%FP and from the Reactivity Control page note the position of the operating point on the attached diagram;
- (2) insert the Malfunction “One Bank of Absorber Rods Drop” (use a five second time delay) and the note the time;
- (3) observe system response on the Reactivity Control page and note the path of the operating point on the attached diagram;
- (4) note OUC mode and reactor power level;
- (5) clear the malfunction;
- (6) once the Absorbers have fully withdrawn from the reactor, raise reactor power to a level dependent on the number of Absorber banks out of the reactor and note the time when maximum reactor power level is reached;
- (7) for each bank partially or fully out, reactor power is limited by 5% (i.e. one bank - 95%FP, two banks - 90%FP, etc).



ASSIGNMENT:

- (a) Explain what happened to OUC MODE and Reactor Power after the malfunction was inserted.
- (b) What is the maximum power level that you could achieve? _____
- (c) How many Adjuster Rods were out of the core? _____
- (d) How long after the insertion of the Malfunction was maximum reactor power achieved? _____

3.4 SDS#1 REACTOR TRIP AND RECOVERY

Check the time calibration factor of the Simulator on your computer, and compute the real time response by multiplying all time measurements taken during this exercise by the time calibration factor.

- (1) Initialize the Simulator to 100%FP;
- (2) manually trip the reactor;
- (3) observe the response of the overall unit;
- (4) wait until Generator power is zero and reactor neutron power less than 0.1%;
- (5) reset Reactor Trip and SDS#1;
- (6) record the time (using the display under the chart recorders) needed to withdraw all shutdown rods, and compute the real time from the measured time;
- (7) raise reactor power to 60%FP, using the following rates of power level setpoint increases:

<u>Actual Neutron Power</u>	<u>Rate of Target Increase</u>
N < 0.5 %FP	0.01 %FP/sec
0.5 < N < 5 %FP	0.1 %FP/sec
5 < N < 20 %FP	0.2 %FP/sec
20 < N < 60 %FP	0.8 %FP/sec

- (8) observe the response of the reactor regulating system and the reactivity changes that take place.

ASSIGNMENT:

- (a) what is the (real) time taken to withdraw all the adjuster rods from the reactor?
- (b) what is the (real) time needed to raise reactor power to 60%FP after the shutdown rods have been withdrawn?

3.5 SDS#1 REACTOR TRIP AND POISON-OUT

- (1) Initialize the Simulator to 100%FP;
- (2) manually trip the reactor;
- (3) observe the response of the overall unit;
- (4) record the value of Xenon reactivity every ten minutes following the reactor trip;

Time (min)	0	10	20	30	40	50	60
Xenon (mk)							

- (5) wait one hour (real time, i.e. measured time X TCF) before resetting Reactor Trip and SDS#1;
- (6) after the shutdown rods have been withdrawn observe the status of the reactivity control devices;
- (7) attempt to raise reactor power – note response;
- (8) note the reactivity changes that have taken place, in particular note the magnitude and estimate the rate of change of Xenon reactivity build-up.

ASSIGNMENT:

- (a) How many minutes after the reactor trip did the last Adjust Rod bank drive out?
- (b) What was the rate of increase of Xenon reactivity at that time (mk/minute)?
- (c) Why is it not possible to raise reactor power one hour after the reactor trip?

3.6 SDS#1 REACTOR TRIP AND POISON OVERRIDE

Before starting this exercise make sure that you do a time calibration of your simulator and that all times calculated and measured are corrected by the appropriate time calibration factor.

- (1) Using the data from the previous two exercises, estimate the time available to the operator from the initiation of the reactor trip until the trip must be reset to avoid a poison outage: the desired end state of this exercise is reactor power at 60%FP and less than one bank of adjuster rods left in the core (i.e. the last bank is partially withdrawn);
- (2) initialize the Simulator to 100%FP;
- (3) manually trip the reactor;
- (4) wait until the above calculated time has expired;
- (5) reset Reactor Trip and SDS#1;
- (6) raise reactor power to 60%FP;
- (7) note the final state of the adjuster rods and Average Liquid Zone level.

ASSIGNMENT:

Note and explain any differences between Poison Override time you computed and the result you obtained, i.e. record the time that elapses between tripping the reactor and recovering reactor power to 60%FP, as well as the number of Adjuster Rod banks not fully withdrawn from the core.

4. HEAT TRANSPORT SYSTEM EXERCISES

4.1 PHT LRV (CV20) FAILS OPEN

- (1) Initialize the Simulator to the 100% full power state;
- (2) record the initial parameter values;
- (3) insert malfunction “PHT LRV (CV20) FAILS OPEN”;
- (4) record the following parameters.

PARAMETER	START	2 min	5 min	10 min	End
Reactor Neutron Power					
Heat Transport (ROH) Pressure					
Pressurizer Pressure					
Pressurizer Level					
Bleed Condenser Pressure					
Bleed Condenser Level					
Feed Flow					
Bleed Flow					
Storage Tank Level					

ASSIGNMENT:

- (a) Why are all Pressurizer Heaters switched ON shortly after the start of the event?
- (b) Why does Pressurizer Level fall?
- (c) After “Bleed Cdvr Pressure” reaches about 8.5 MPa, why does it fluctuate?
- (d) What will happen if this condition is allowed to continue for several hours?
- (e) What should the unit operator do to ensure reactor safety?

4.2 PHT STEAM BLEED VALVE (CV22) FAILS OPEN

- (1) Initialize the Simulator to the 100% full power state;
- (2) record the initial parameter values;
- (3) insert malfunction “PHT STEAM BLEED VALVE (CV22) FAILS OPEN”;
- (4) record the following parameters.

PARAMETER	START	2 min	5 min	10 min	End
Reactor Neutron Power					
Heat Transport (ROH) Pressure					
Pressurizer Pressure					
Pressurizer Level					
Bleed Condenser Pressure					
Bleed Condenser Level					
Feed Flow					
Bleed Flow					
Storage Tank Level					

ASSIGNMENT:

- (a) Why is Pressurizer Level decreasing after the malfunction is inserted?
- (b) Why is ROH Pressure decreasing?
- (c) Why does the Reactor Trip?
- (d) What corrective action should the unit operator perform to prevent the Reactor Trip?

4.3 PHT FEED VALVE (CV12) FAILS OPEN

- (1) Initialize the Simulator to the 100% full power state;
- (2) record the initial parameter values;
- (3) insert malfunction “PHT FEED VALVE (CV12) FAILS OPEN”;
- (4) record the following parameters.

PARAMETER	START	2 min	5 min	10 min	End
Reactor Neutron Power					
Heat Transport (ROH) Pressure					
Pressurizer Pressure					
Pressurizer Level					
Bleed Condenser Pressure					
Bleed Condenser Level					
Feed Flow					
Bleed Flow					
Storage Tank Level					

ASSIGNMENT:

- (a) What are the initial consequences of the increased Feed flow?
- (b) Which control system responds to correct the excess Feed flow? What is the controller action?
- (c) What corrective action could the unit operator take?

4.4 PRZR SURGE VALVE (MV1) FAILS CLOSED

- (1) Initialize the Simulator to the 100% full power state;
- (2) record the initial parameter values;
- (3) insert malfunction “PRZR SURGE VALVE (MV1) FAILS CLOSED”;
- (4) in “NORMAL” OUC Mode lower generator output to 50% at a rate of 0.5%FP/sec;
- (5) record and explain the changes in the following parameters.

PARAMETER	START	2 min	5 min	10 min	End
Reactor Neutron Power					
Heat Transport (ROH) Pressure					
Pressurizer Pressure					
Pressurizer Level					
Bleed Condenser Pressure					
Bleed Condenser Level					
Feed Flow					
Bleed Flow					
Storage Tank Level					

ASSIGNMENT:

- (a) What is the consequence of this malfunction if there is no change in reactor power level?
- (b) What is the consequence of this malfunction when the power level is changed?
- (c) What corrective action should the unit operator take?

4.5 PHT BLEED VALVE (CV5) FAILS OPEN

- (1) Initialize the Simulator to the 100% full power state;
- (2) record the initial parameter values;
- (3) insert malfunction “PHT BLEED VALVE (CV5) FAILS OPEN”;
- (4) record and explain the changes in the following parameters.

PARAMETER	START	2 min	5 min	10 min	End
Reactor Neutron Power					
Heat Transport (ROH) Pressure					
Pressurizer Pressure					
Pressurizer Level					
Bleed Condenser Pressure					
Bleed Condenser Level					
Feed Flow					
Bleed Flow					
Storage Tank Level					

ASSIGNMENT:

- (a) What are the initial consequences of the increased Bleed flow?
- (b) Which control system responds to correct the excess Bleed flow? What is the controller action?
- (c) What corrective action could the unit operator take?

5. STEAM AND FEEDWATER SYSTEM EXERCISES

5.1 FW LCV101 FAILS OPEN

- (1) From a Simulator Initial state of 100% full power, insert the malfunction "FW LCV101 FAILS OPEN";
- (2) observe unit response on "Steam Generator Level Control" and "Steam Generator Level Trend" displays.

ASSIGNMENT:

- (a) What are the main system responses?
 - (b) What would the Operator need to do to maintain power production?
-
- (3) Repeat the above but view only the "Plant Overview" page until the alarm "Stm Gen Level Hi" is received.
 - (4) Take the appropriate Operator actions to maintain power production.

5.2 FW LCV101 FAILS CLOSED

- (1) Initialize the Simulator to 100 %FP;
- (2) change 'Control Mode Select' to OPERator and select 3-ELEment control for SG1 and SG3;
- (3) for SG1 change selection of LCV from #3 to #1;
- (4) after feedwater and boiler level transients are over, insert malfunction "FW LCV101 FAILS CLOSED".

ASSIGNMENT:

- (a) Explain the responses of feedwater flow, steam flow and pressure, and boiler level on all four steam generators.

- (5) Initialization the Simulator to 100 %FP;
- (6) change 'Control Mode Select' to OPERator and select 1-ELEment control for SG1 and SG3;
- (7) for SG1 change selection of LCV from #3 to #1;
- (8) after feedwater and boiler level transients are over, insert malfunction "FW LCV101 FAILS CLOSED".

ASSIGNMENT:

- (b) Explain the responses of feedwater flow, steam flow and pressure, and boiler level on all four steam generators.
- (c) Explain the main differences in response between (a) and (b).

5.3 STEAM GENERATOR #1 FW FT IRRATIONAL

- (1) Initialize the Simulator to 100 %FP;
- (2) insert malfunction "STEAM GENERATOR #1 FW FT IRRATIONAL".

ASSIGNMENT:

- (a) Explain the responses of feedwater flow, steam flow and pressure, and boiler level on all four steam generators.
- (b) What would be the correct operator action?

- (3) Initialization the Simulator to 100 %FP;
- (4) insert malfunction "STEAM GENERATOR #1 FW FT IRRATIONAL";
- (5) perform the correct operator action.

ASSIGNMENT:

- (c) Explain the responses of feedwater flow, steam flow and pressure, and boiler level on all four steam generators.
- (d) Explain the main differences in response between (a) and (c).

5.4 STEAM GENERATOR PRESSURE CONTROL EXERCISE

Using Simulator pages 'Plant Overview', 'Turbine-Generator' and 'UPR', design a procedure to verify the following features of the Steam Generator Pressure Control program:

(1) the boiler pressure error at which the ASDVs open

(2) the boiler pressure error at which the CSDVs open

(3) the % reactor power to which the steam flow through 100% open ASDVs corresponds

- final reactor power
- final generator power
- % reactor power through ASDVs
- governor valve opening

ASSIGNMENT:

Describe your procedure and record the results.

5.5 REACTOR TRIP AND UNIT RECOVERY

- (1) Initialize the Simulator to 100 %FP;
- (2) manually Trip the Reactor;
- (3) confirm Reactor Trip (neutron power decreasing rapidly, all shutdown rods in the core);
- (4) once Neutron Power is below 0.01 %FP and Turbine speed is at 5 RPM, begin power recovery operation;
- (5) reset Reactor Trip;
- (6) raise Reactor Power to 10 %FP, using the following rates of power level setpoint increases:

<u>Actual Neutron Power</u>	<u>Rate of Target Increase</u>
N < 0.5 %FP	0.01 %FP/sec
0.5 < N < 5 %FP	0.1 %FP/sec
5 < N < 10 %FP	0.2 %FP/sec

- (7) reset Turbine Trip, select 'TRU ENABLE', synchronize the generator and load to about 10 %FP;
- (8) in ALTERNATE mode raise Reactor Power and Generator Power to a level determined by the number of Adjuster Rod banks not fully in the core:

$$\text{FINAL POWER} = 100\% \text{FP} - (5 \times \text{number of rod banks not fully in core})\%$$

ASSIGNMENT:

- (a) Record the reactor (%FP) and generator power level (%FP and MW) reached when power recovery has been completed.
- (b) Ensure that for the allowed reactor power the generator is producing the maximum power.
- (c) How many Adjuster Rod banks were not fully in the core when the maximum power production recorded in (b) was achieved?

6. OVERALL UNIT EXERCISES

Begin each of the following exercises from the Plant Overview page. Initialize the Simulator to 100% FP. Before inserting the specific malfunction, change the plot parameter limits as follows:

Reactor Power minimum value	80 %
Turbine Power minimum value	80 %
Main Steam Header Pressure lower limit	4000 kPa
Pressurizer and ROH Pressure lower limit	9000 kPa
Pressurizer level and Setpoint	6 m

After inserting the malfunction (use a 5 second delay), note the main system responses, and how you can identify each malfunction, or at least identify the system (and simulator display) where the malfunction is most likely to be found.

6.1 FAIL CLOSED ALL FEEDWATER LEVEL CONTROL VALVE MOTORIZED VALVES

- (1) Observe the main parameter changes that take place in the first minute, in particular Reactor Neutron and Thermal Power, Pressurizer Level and Setpoint, Boiler Levels, PRZR/ROH Pressure, Steam Generator Pressure, Feedwater Flow.
- (2) Once Reactor Setback is initiated, freeze the simulator.

ASSIGNMENT:

- (a) Describe the main parameter changes including the above, and write a brief explanation for the parameter changes in terms of the process system responses and the control system responses.
- (3) Unfreeze (RUN) the simulator and clear the malfunction.
- (4) Place each SG level control MV on Manual and OPEN.

ASSIGNMENT:

- (b) In what sequence should the MVs be open? Why?
- (5) Raise reactor power and generator output to 100% FP and return to Turbine-leading-Reactor mode of unit control.
- (6) Check that all equipment states and parameter values are consistent with 100% FP condition.

6.2 ALL MAIN BFPs TRIP

ASSIGNMENT:

Describe the unit's response and explain the main differences between the responses to this malfunction and the one in exercise 6.1.

6.3 TURBINE SPURIOUS TRIP

ASSIGNMENT:

- (a) List the initial alarms after the malfunction had been inserted.
- (b) Describe the “state” (main energy balance) of the unit.
 - Reactor Power
 - Heat Transport ROH Pressure
 - Steam Generator Pressure
 - Generator output

One minute after inserting the malfunction, freeze the simulator.

- (c) Describe the response and effect of each of the main control programs:
 - BPC
 - UPR
 - RRS
 - TRU
 - BLC
 - PHTP&I
 - PRZR Level

Run the simulator for 5 minutes and again observe the response and effect of each of the main control programs.

- (d) Briefly describe and explain the response and effect of each of the main control programs. Note the value of key parameters after one and further five minutes.
- (e) What operator actions are required?

Remove the malfunction and return the unit to maximum generator output permitted by the reactor (i.e. 100 %FP - 5% for each Adjuster bank not fully in the core).

- (f) What was the maximum power level reached above and how many Adjuster Rod banks were not fully in the core?

6.4 THROTTLE PT (PRESSURE TRANSMITTER) FAILS LOW

ASSIGNMENT:

- (a) List the initial alarms after the malfunction had been inserted.
- (b) Describe the “state” (main energy balance) of the unit:
 - Reactor Power
 - Heat Transport ROH Pressure
 - Steam Generator Pressure
 - Generator output
- (c) Observe and explain the response and effect of each of the main control programs:
 - BPC
 - UPR
 - RRS
 - TRU
 - BLC
 - PHTP&I
 - PRZR Level

When Main Steam Header Pressure recovers to < 5000 kPa, Clear the malfunction.

Raise Reactor power to 60 %FP.

Reset turbine trip.

Load generator to 60 %FP.

- (d) Explain what further steps and precautions you would take in raising unit output to 100%FP.

6.5 RIH#1 SMALL BREAK

- (a) List the initial alarms after the malfunction had been inserted.
- (b) Describe the “state” (main energy balance) of the unit.
 - Reactor Power
 - Heat Transport ROH Pressure
 - Steam Generator Pressure
 - Generator output
- (c) Observe and explain the response and effect of each of the main control programs:
 - BPC
 - UPR
 - RRS
 - TRU
 - BLC
 - PHTP&I
 - PRZR Level
- (d) What specific Heat Transport System parameter(s) identify the loss of coolant from the main circuit?

After the malfunction is identified (5 - 10 minutes) remove the malfunction and return the unit to full power operations.

- (e) Explain what precautions you would take in raising unit output to 100%FP.

6.6 MAIN STEAM HEADER BREAK

- (a) List the initial alarms after the malfunction had been inserted.
- (b) Describes the “state” (main energy balance) of the unit.
 - Reactor Power
 - Heat Transport ROH Pressure
 - Steam Generator Pressure
 - Generator output
- (c) Observe and explain the response and effect of each of the main control programs:
 - BPC
 - UPR
 - RRS
 - TRU
 - BLC
 - PHTP&I
 - PRZR Level
- (d) What specific Steam System parameter(s) identify the loss of steam from the system?